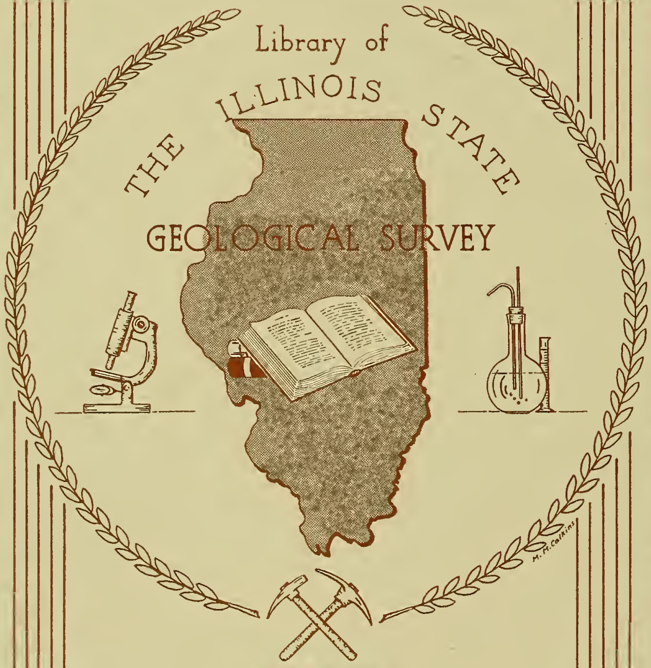
Library of
THE ILLINOIS STATE
GEOLOGICAL SURVEY

URBANA



STATE OF ILLINOIS
HENRY HORNER, *Governor*
DEPARTMENT OF REGISTRATION AND EDUCATION
JOHN J. HALLIHAN, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*
URBANA

CIRCULAR NO. 23-C

CURRENT DEVELOPMENTS IN CLAY AND CLAY PRODUCTS

EXTRACT OF THE CONTRIBUTIONS OF THE FIFTH ANNUAL ILLINOIS MINERAL INDUSTRIES CONFERENCE

AUG. 26TH 1818

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
1938

Contributions of the
FIFTH ANNUAL MINERAL INDUSTRIES CONFERENCE

October 8-9, 1937
Urbana, Illinois

Sponsored by

The Illinois State Geological Survey Division of the Department of Registration and Education

The Engineering Experiment Station of the University of Illinois

The Illinois Mineral Industries Committee

In cooperation with

American Institute of Mining and Metallurgical Engineers, Chicago and St. Louis Sections
American Mining Congress
Belleville Group Coal Association
Chicago Face Brick Bureau
Coal Producers' Association of Illinois
Combustion Engineering Council
Committee of Ten—Coal and Heating Industries
Illinois Chamber of Commerce
Illinois Clay Manufacturers' Association
Illinois Coal Operators' Association
Illinois Coal Traffic Bureau
Illinois-Indiana Petroleum Association
Illinois Mining Institute
Illinois Sand and Gravel Association
Illinois Society of Engineers
Midwest Agricultural Limestone Institute
National Crushed Stone Association
National Lime Association
State Department of Mines and Minerals
State Division of Highways
St. Clair-Madison County Coal Operators Association
Western Society of Engineers

Although published by the Illinois State Geological Survey Division, the Survey assumes no responsibility for statements made in papers herein.

ALLIED PRINTING TRADES UNION LABEL COUNCIL SPRINGFIELD ILL. 7
(49804)

CONTENTS*

Page
Comparative Status of Clay Mineralogy in Europe and the United States, by R. E. Grim 5
Progress, Possibilities, and Limitations in the Beneficiation of Clays, by G. A. Bole....... 11
New Developments in the Processing and Forming of Clay Products, by R. K. Hursh..... 19
Unexploited or Little Known Industrial Minerals of Illinois, by J. E. Lamar............. 27
Magnetic Separators and Their Possible Applications to the Beneficiation of Illinois Industrial Minerals, by J. J. Ferris.. 47

---

* The manuscript "Production of Beidellite Clay and Its Uses," by J. L. Essex, Chief Engineer, Illinois Clay Products Company, Chicago, was not submitted for publication.

ILLUSTRATIONS

Figure. Page
1. Potash shale and greensand deposits in Illinois.. 29
2. Mechanical composition of coarse and fine sands of southern Illinois................ 40
3. Comparison of Illinois brines with those from other states........................ 41
4. Location and composition of resin-bearing limestones............................... 42
5. Area of gypsiferous limestone in central and southwestern Illinois.................. 42
6. Relative percentages of gypsum, anhydrite and limestone in the core of a well in southeastern Macoupin County.. 43
7. Demonstration of the pull exerted by a magnetic wheel of high intensity............ 48
8. New air-cooled serrated magnetic pulley.. 49
9. Diagram of a high intensity magnetic separator...................................... 51
10. A 30-inch, five rail type of magnetic separator.................................... 52

Digitized by the Internet Archive
in 2012 with funding from
University of Illinois Urbana-Champaign

http://archive.org/details/currentdevelopm23cmine

CURRENT DEVELOPMENTS IN CLAY AND CLAY PRODUCTS

COMPARATIVE STATUS OF CLAY MINERALOGY IN EUROPE AND THE UNITED STATES

By

R. E. Grim

Petrographer, Illinois State Geological Survey

It was the writer's privilege to attend the scientific sessions and excursions of the International Geological Congress in Russia this past summer. A number of European laboratories in which the constitution of clay is actively being studied were visited before and after the activities of the Congress. In the time allotted some of the ideas and thoughts gained as a result of these visits will be presented. At the outset, however, it is necessary to consider very briefly and in very general terms the present concepts on the mineral constitution of clays.

The problem of the mineral composition of clays is a very old one and one that has occupied the attention of investigators for many years. It is rather easy to identify the coarser constituents of clay by means of the petrographic microscope but it is not easy to investigate the constitution of the finest—the so-called colloidal fractions of the clays. It is this finest fraction that is most important in determining what the properties of a given clay shall be. Early work on this problem was mainly chemical in nature and a large body of valuable data are available as a result of this study. It did not, however, provide an adequate picture of the constitution, particularly the mineral constitution of this material, and it was not possible to explain satisfactorily the variations in the properties which different clays are known to possess on the basis of this early work.

About ten years ago with the advent of X-ray diffraction analysis a new procedure was made available for studying the finest fraction of clays and shales. Since that time there has been renewed interest in this problem and several laboratories in various countries have been actively engaged in investigating the exact constitution of clays. In the last few years microscopic technique has been improved so that now it is possible to carry the petrographic analyses with the microscope to smaller particles than was formerly possible. Also it has been found possible to apply microscopic technique to aggregates of extremely minute particles which cannot be seen individually.

In addition to these improvements the use of the supercentrifuge has been applied to clay researches and this apparatus has permitted the relative purification of mineral constituents in the colloid size range. All of this recent work has served to establish the thesis that clays and shales are essentially composed of extremely minute particles of one or more of a group of minerals which have come to be known as the clay minerals. The most important clay minerals are kaolinite, montmorillonite-beidellite and their iron end member nontronite, and illite. There are other clay minerals but information to date would suggest that these three are the most important ones. Clays and shales may contain varying amounts of quartz, calcite, organic material, etc., in addition to the clay minerals, which are mainly compounds of alumina, silica, and water.

One of the important pieces of work being done in European laboratories is the mineralogical analysis of all types of clays with these new techniques. Here in Illinois we are carrying on similar work in our attempt to catalog completely the kinds of clays we have in the State and the types of clay which may be used in various industries and which are not now produced in Illinois. The exact procedure used in making these mineral analyses is not the same in all laboratories. In Germany it is generally felt that X-ray analyses alone are sufficient to determine the mineral composition of clays. Here we are of the opinion that a satisfactory determination of the mineral composition of clays and shales can only be gained by X-ray, optical and chemical analyses.

All of this work on the constitution of clays is leading, or in some cases has already led, to the investigation of the influence of specific clay minerals on the ceramic and physical properties of clays. It is important to know what properties a clay composed of montmorillonite will have which a clay composed of kaolinite will not have, etc. A considerable amount of work in this direction has been done and is being done in our own laboratory and in certain laboratories in Germany. This work has indicated the conclusion that the clay mineral constituent is perhaps the most important factor determining the properties of the clay itself. For example, in general clays composed of kaolinite are refractory, not very plastic, and possess low bonding strength, whereas clays composed of montmorillonite are very plastic, not refractory, and have high bonding power. The information being gained from this work would seem to indicate that for the first time we are obtaining a reasonable answer to the question—why do certain clays possess the properties they do? It is becoming possible, for example, to understand why the famous Gros Almerode glass pot clays possess a long vitrification range and low shrinkage. The answer seems to be the presence of a large amount of very small quartz grains, the size of the particles of the chief constituent (kaolinite), and the presence of a small amount of montmorillonite.

In order to fully understand the influence of various clay minerals on physical properties it is necessary to know in detail all of the characteristics of the pure clay minerals themselves and at the present time a large amount of work is being done on this problem in laboratories in England, Holland, France, and Germany. As a result we are beginning to obtain a satisfactory picture of the lattice structure of these minerals. There are many problems still to be solved before these structures will be fully understood. By following the work of Pauling a considerable body of information on this subject is now available. A large amount of work has been done in the past on the influence of heat on kaolins in which kaolinite is the chief constituent. At the present time the influence of heat on the other clay minerals is actively being investigated. This work is of great importance as it forms the basis of an understanding of refractoriness in clays. It is also necessary to completely understand the durability of clays which are used in preparing synthetic molding sands, and it forms the basis of attempts which are continually being made to use clays as the source of metallic aluminum. In this connection it is interesting to note the work which has been done in this country on the influence of variations in particle size of certain clay minerals as they are subjected to elevated temperatures. The results of this work are not yet clear and at the present time data obtained in certain European laboratories do not seem to check results obtained by American investigators.

In the last three or four years active work has been carried forward in Germany and in two American laboratories on the synthesis of clay minerals. Unfortunately the work of the German laboratory which up until now has been most active in this field has been halted; perhaps it will be taken up elsewhere in that country. It has been possible to produce synthetically a large enough amount of kaolinite to produce some burned ware from it. The object of burning the ware was to determine the ceramic properties of the synthetic kaolinite. There is no thought yet of any commercial application but the work will bear close watching. This work on the synthesis of clay minerals has greatly increased our understanding of the conditions under which these minerals form in nature, and the range in which they are stable.

Various mineral materials possess a property which is known as base exchange capacity. Perhaps the phenomena of base exchange can be visualized best by reference to the zeolite or permutite water softeners. Water is hard because it contains calcium compounds, popularly known as "lime." As the hard water passes through the zeolite softener the calcium of the water is exchanged for sodium which the zeolite originally contained. That is to say, sodium goes from the zeolite to the water in exchange for calcium which goes from the water to the zeolite thereby softening the water. Passing a salt solution through the softener reverses the process, reviving the softener. Soil investigators have known for many years that the colloidal fraction of most soils possess this property of carrying bases which are exchangeable under certain conditions for other bases. About five years ago a group of German investigators presented an outstanding contribution to the study of the constitution of clays and shales in which they pointed out the capacity of various clay minerals to carry exchangeable bases. They also indicated the exchange capacity of various types of clay and made the further extremely important contribution by indicating that the physical properties of clays with appreciable base exchange capacity varied with the exchangeable base that was present. For example, given clays will have different plasticities depending upon whether sodium or calcium is present in the clay as the exchangeable base. Of course it has been known by ceramists for many years that some properties of clays could be varied by treating them with acids and alkalis but the concept of base exchange in clays provides, perhaps for the first time, a satisfactory fundamental basis for understanding exactly how the properties are influenced by various chemicals. It seems to the writer that this is a fundamental approach to an understanding of clay properties which holds great promise for the development of means whereby the properties of a given clay may be controlled and improved.

At the present time a very large amount of work is being done in many laboratories on the general subject of base exchange in relation to clay constitution. Already we have information which would indicate the exchange capacity of the different clay minerals. Work is actively being carried on in an attempt to determine the reasons why clay minerals possess their characteristic exchange capacities. Various papers have appeared and work is being continued in an attempt to determine the relation of exchangeable bases to the lattice structures of the minerals. Thus an English investigator, who in the last few months has moved to this country, has suggested that base exchange is related to the presence of an expanding lattice structure which certain clay minerals possess. By an expanding lattice is meant the property of certain clay minerals to expand in one direction with the addition of small amounts of water. The whole problem of the causes of base exchange and the factors controlling it is at the present time, far from being solved. The work now being done will, it is hoped, enable us to fully understand base exchange.

In the Survey laboratory investigations are in progress studying the influence of specific exchangeable bases on the physical and ceramic properties of clays. It is planned to determine if possible exactly how exchangeable calcium, sodium and other alkalis and alkaline earths will influence the properties of Illinois clays and shales. It was a pleasure to learn this summer that a similar piece of research is just being started on English clays. In Germany also work in several laboratories is being carried forward in this direction.

One point in regard to base exchange in which there is considerable interest and considerable disagreement among investigators at the present time is the influence of extreme grinding on exchange capacity. On the basis of their work, one American laboratory has concluded that the exchange capacity of certain minerals can be very greatly increased by extreme grinding. The importance of such a finding is evident in view of the importance of exchangeable bases and base exchange generally on the physical properties of clays. Various German investigators have attempted to duplicate this work and so far have not been able to obtain the same results as the American investigators. Perhaps within the next year or two more will be known about this matter.

In recent years there has been a great deal of interest in European countries in bentonite. The literature of the last year or two is filled with references to new deposits of bentonite which have been found. Germany, for example, has found that it has large scattered deposits of this type of clay. Russia has large deposits of bentonite. The interesting feature of much natural German bentonite is that it possesses few of the physical properties characteristic of American bentonites for the reason that it contains calcium as the exchangeable base whereas much of our bentonite contains sodium as the exchangeable base. Some German bentonite producers are now treating their clay in order to exchange its calcium for sodium before it is put on the market.

German and Austrian engineers interested in soil mechanics have been doing some interesting work in recent years by passing an electrical current through clay, noting its effect on the physical properties. They have shown, for example, that with this treatment it is possible to increase the loading strength of a very plastic clay. This work is being carried further and at the present time some very interesting research is being done in Austria on the influence of electrical current on other physical properties of clays and clay suspensions. It is the writer's opinion that such work will warrant careful watching to see whether or not it has any practical application in the utilization of clay and shales.

The rather widespread use of natural rocks for refractory purposes was one of the impressive things revealed in talking with European clay men. As is well known, that is being done to some extent in this country—certain hard stones have been used for refractory purposes—but there seemed to be more interest in such refractory material in those countries than in our own. Germany, for example, is using rather extensively a slightly laminated sandstone for this purpose. One of the desirable properties possessed by this rock is its ability to break rather easily into slabs an inch or two in thickness. In Russia it was interesting to learn of the use of a slightly weathered igneous rock for refractory purposes in an unfired condition. It wasn't possible to learn very much about this material but it was understood that the natural material is quarried in regular blocks and then heated to a temperature of only a few hundred degrees Centigrade before it is used for furnace linings. A distinct impression of the growing importance of raw and semiraw rocks for refractory purposes was gained.

During the visit to Germany the writer was fortunate enough to visit the Gros Almerode clay deposit near Kassell which is well known for the production of glass pot clays. This clay occurs between beds of low grade coal and in somewhat the same way as does the underclay in this State. Great care is taken in this clay producing plant to insure uniformity of the product produced. As the clay comes from the mine it is moved along a conveyor belt where impurities are picked out by hand, and the larger pieces of clay are broken apart by hand in order that no impurity shall escape detection. Much of this clay is burned at the plant and sold as grog for making glass pots. After the clay comes from the kiln it is again hand picked in order to remove all impurities.

One of the reasons for the visit to this plant was that it contains one of the few electro-osmosis installations for the purification of clays. Briefly this is a procedure making use of the difference in electrical properties of the clay mineral particles and the impurities for the elimination of the latter. The process is quite expensive, however, and can only be used on a product which commands a very high price.

It was the writer's good fortune to travel about 13,000 miles in Russia this summer in the two months spent there. A visit to the Ceramic Research Institute at Kharkov could not be arranged and consequently it is not possible to discuss the work being done there. As a result of conversations with various Russian scientists it is believed that the Russians have done little work on their clays up to the present time. They seem to be just beginning the intensive search for various types of clays and the intensive studies of the properties of the clays which the country possesses. It is logical that the search for and the study of clays should follow the intensive search for metallic resources. The Russians in the last ten or fifteen years have intensively searched their country for natural resources. They claim that there are 40,000 geologists in Russia and although this figure cannot be vouched for, there are certainly a lot of them and a great amount of study is being done on their natural resources. These are not only being studied in the field—their properties are being studied in the laboratory. Research institutes for every conceivable branch of science have been established; frequently not one for a given field, but several, located in different parts of the country. Russian scientific literature is appearing in tremendous volumes. It will be increasingly important for those engaged in clay research in this country to follow the results of the work on Russian clay investigations.

PROGRESS, POSSIBILITIES AND LIMITATIONS IN THE BENEFICIATION OF CLAYS

By

G. A. Bole

Research Professor, Engineering Experiment Station,
Ohio State University, Columbus

When your Chairman asked me to talk on the beneficiation of the common clays, I demurred, stating that I should prefer to eliminate the word "common" from the title, thinking, of course, to include those pottery clays on which so much work has been done in the recent past. Dr. Leighton reminded me in the meantime that a large proportion of the attendance was interested in information having to do with the common clays and their use in industry. Realizing the limited time at my disposal, I have accordingly decided to stress the common clays, although I shall review briefly the work on the pottery clays to give us a background for a study of the common clays. I shall have time to do little more than tabulate the things that have been done in the field.

I should like to expand the term "beneficiation" in this instance to include any process or device which will render the clay better suited to the production of a marketable ware. This is probably an undue expansion of the more technical meaning of the term, but we shall consider it in this light in the present manuscript. The concentration engineer will probably have a much more narrow conception of "beneficiation", including only those modern processes which have to do with flotation, tabling, electrostatic, and electromagnetic methods. The ceramic engineer, on the contrary, is interested in the problem from the standpoint of product only.

The difficulties encountered in the fabrication of a ceramic product have to do with the way the material flows through the die, how it dries and fires. All this, on the other hand, usually harks back to the properties of the raw material, although certain modifications in the handling of the material may account for failure in the product.

Dr. Ralston reports that the U. S. Bureau of Mines did considerable work on the froth flotation of North Carolina kaolin in cooperation with one of the companies producing the kaolin. He reports that froth flotation using the cationic type reagents recovers the clay in six stages: (1) colloidal clay, (2) kaolinite, (3) weathered mica, (4) unweathered muscovite, (5) quartz, and (6) feldspar. The recovery is made by using different concentrations of the reagent. Whether this method of handling the clay would be an advantage would depend upon quite a few items, the most important being a study of the middlings obtained between each fraction. The separation could doubtlessly be halted before the weathered mica fraction which would give all the useable clay fraction and leave the other fractions for use in other fields. The drawback with any of these highly specialized flotation methods is to secure a favorable market for the by-products. To digress only a moment, we find that the by-products from the concentration of cyanite, such as the mica, the garnets, and the sand, constitute the real problem in the economical production of a high grade cyanite. The same problem is met in the beneficiation of the North Carolina kaolin. These kaolins contain only 15 to 18 per cent of recoverable kaolin, about 10 per cent mica, and a varying percentage of feldspar of questionable utility, although it is just possible that it will be of a grade useable by the soap manufacturers.

A second method of handling these kaolins consists of deflocculating, cleaning, and flocculating them, much the same as is done in the Zettlitz area of Czechoslovakia. A product is thus obtained that will be quite acceptable to the pottery industry. At one or two of the Zettlitz plants the clay is dewatered in an electro-osmotic filter instead of filter presses, as is the custom in this country. The electro-osmotic process was tried out on the Carolina kaolin with excellent results, but it was thought to be unnecessary to produce a high grade product from the raw material available.

Marketing the by-products to advantage is seen to be a vital problem when you consider that only from 15 to 18 per cent of the mined material comes out as pottery clay. The production of a fine-grained material from the hard granular kaolin is a problem that has worried the producers of kaolin. Recently two or three methods have been worked on, but are held as plant secrets by the respective companies.

One of the Georgia kaolin companies used to have an elaborate system of beneficiation which, to the casual observer, worked wonders, but it has been abandoned, so I presume there were some drawbacks which were economically insurmountable. The clay was taken from the pit and put through a rod mill and from there it went to a cone classifier, and then to a Dorr thickener, where it was partially dewatered. This was followed by complete dewatering on a rotary filter. The filter consisted of a revolving drum which dipped into the thick clay slip. The drum was heated internally. The clay was removed from the drum to an endless belt which carried it to a rotary drier.

Mr. Stull, while with the Bureau of Mines, worked out a cone classifier that was used by a company to produce a superior product from their Georgia kaolin deposit. The theory of the apparatus was based on the fact that the clay stream was introduced tangentially. Mr. Stull explained that the material as it sank, due to the influence of gravity, was swished in layers of water traveling at different rates, thus causing the mica particles to dive as well as sink because of their gravity. The influx of the clay-bearing water was some inches below the overflow. The sand and mica were accordingly settled out in the cone and the clay-bearing water was received in a trough around the periphery of the cone. The clay slip was deflocculated at the outset and flocculated in the storage tank that followed the cone classifier. The concentrated slip was, of course, filtered in presses.

The use of an air-floated ball clays adds economy and convenience to the mixing of the clay batch in that bodies formerly mixed wet can now be mixed dry. The recent development of machines for mixing the dry batch has made such a procedure possible. This illustrates that a clay which can be used in a simple way in a plant process can stand some added beneficiation cost.

Another method largely used consists of deflocculating the clay and degritting the slip, the latter process throwing out approximately 15 per cent of the crude material. The remainder is then separated into two fractions by centrifugals under controlled conditions. The coarse fraction is used by the paper industry in manufacturing a more highly ink-receptive sheet. The ceramic trade also uses this fraction, as it has low shrinkage, fast casting qualities and helps in the filtering of high ball clay bodies. The fine fraction is used entirely by the paper industry to obtain a high gloss on coated paper.

With these few observations on the cleaning of the kaolins we shall now consider the progress that has already been made on common clays. In the northern part of the United States there is a belt of glacial clays. These clays have been transported by the glacial drift and deposited as moraine material. They carry as incidental those materials picked up along the path of the glacier. A great deal of the surface clay of northwestern Ohio, Indiana, and Illinois is of this type. These clays are infested with pebbles, the most objectionable of which are the lime pebbles. When the clays are made into a ware and exposed to the elements, we have "popping" due to the slow slaking of the lime. The slaking can be controlled by fine grinding, firing to an advanced temperature, or by the addition of chemicals to the clay which causes a vitrification at the lime-clay interface. The Germans have a treatment that inhibits popping. They immerse the fired ware in water, which causes a quick slaking, which apparently the brick structure is able to withstand. All this sounds very simple, but experience has taught that it is a relatively expensive job to fine grind the material sufficiently to obviate the objectionable features.

An additional objection to the use of these clays is that a high lime clay has a short firing range. This objection, when coupled with the necessity of firing to an advanced temperature, renders the clay very difficult to handle.

With these things in mind, it is common experience that pebbles must be avoided in the harvesting of the clay or must be removed before the clay is ready to be made into ware. To this end, a great many things have been tried.

The simplest and most direct remedy is accomplished by a piece of equipment known as a clay cleaner and brick machine. Clays of this type are wet during certain seasons of the year, and if undried, come to the machine in a semiplastic condition. These clay cleaners will handle the wet clay reasonably efficiently. The better ones consist of a series of rolls, the underlying principle being that the larger pebbles are removed in the conical rolls and the smaller pebbles are ground through a pair or pairs of smooth rolls. From this point the clay enters the brick machine proper and is pugged and delivered to the molds.

As you can readily see, this type of machine eliminates only the larger pebbles and imperfectly grinds the smaller. If the clay does not have too great a proportion of fine pebbles, the product is acceptable; if the proportion of fine pebbles is excessive, the ware is either unusable or on the borderline of usability. Plants in Chicago, Detroit, Toledo, and Cleveland have used these machines.

The best way of handling these clays consists of drying them in rotary driers. The dried clay is freed of the pebbles in a dry pan—usually a pan with the mullers raised so as not to crush the pebbles. The clay is then screened through a revolving screen and delivered to the pug mill. These pebbles are often so clean that they can be sold as cement aggregate.

A very old method and one never largely used consists of a whipping device which cleans the clay and eliminates the pebbles. The only record we have of the use of such a machine is given by Mr. Richardson at a plant in Minnesota of which he was superintendent. Mr. Richardson is quite convinced that it is one of the best devices yet brought forward for cleaning crude clays of pebbles.

Another suggested device is a machine made in Germany and in England which consists of a series of slots in the end of the barrel of an extruding machine much the same as the slots in the present day de-airing machines. These slots are one-sixteenth of an inch or less and so stop the passage of the pebbles. The barrel is opened periodically, and the pebbles cleaned out. It would seem likely that the method would cut down production unduly, but is a suggestion that has worked in small production plants.

One or two cases of washing have been reported in the literature. A variety of methods might be used. The commonest is to blunge the clay, screen out the pebbles, and allow the slip to settle, after which it is used as a pebble-free raw material. Drawings showing such a device are available and can be had for the asking.

A modification taken from the kaolin washeries would be to float the clay with an electrolyte in the blunger, screen, and flocculate it, causing rapid settling followed by the removal of the supernatant liquid.

These five methods are, with an infinite number of modifications, commercially the most widely accepted procedures for handling the problem of pebble removal.

Several investigators have tried the action of common salt on the lime to inhibit slaking. Common salt and other chemicals are put in the pug water and during firing, flux the lime to form a high lime soda glass which forms a vitreous interface between the clay body and the lime, thus reducing the harmful popping. Mr. Heath in our laboratory showed quite graphically the effects of using salt on clays containing lime pebbles of various size, from ten mesh down to forty-eight mesh. He also showed the effect of various degrees of firing.

One of the oldest and most efficient ways of beneficiation (our definition of beneficiation) is to mix one clay with another to give it the properties desired to make it act properly in the machine, in the driers, or in the kiln. A strong plastic clay is often added to a weak clay. A clay that shrinks unduly is some times corrected by the addition of sand or a sandy clay. Another method of handling the clays that have too high a shrinkage is to calcine them at a low temperature, thus driving off the mechanically held water. The heating destroys the colloidality of the clay, making it less plastic.

Certain strata of a pit often have to be avoided to give a clay that will make a good product. Not far from here is a plant that was having undue drier and kiln losses. After a large amount of study it was found that the upper few inches of their shallow pit had to be eliminated, if these kiln losses were to be stopped—this in spite of the fact that this top clay was one of the most remarkable clays I have ever seen. It had a dry modulus of rupture of 1,800 pounds per square inch. This clay, however, caused the losses suffered in their driers and kilns.

One of the most popular and recent methods of treating clays to improve the quality of the product is the partial elimination of air in the pug mill. Machines for doing this are now being made by nearly all the clay machinery manufacturers. The first successful commercial machine was put out by the Bonnot Company some ten years ago. We at Ohio State had a hand in proving the efficiency of this machine. De-airing will eliminate such difficulties as blisters and will apparently eliminate lamination in ware, although with a good many clays the laminations are still there but are not apparent to the casual observer. The clay usually flows through the die much more readily and the column has a very tough, flexible texture. The clay industry was astounded at the first experiments showing the possibility of extruding long unsupported columns, and small columns that could be tied in knots. The experiments were very spectacular.

While de-airing has doubtlessly done a great deal for the clay industry, it has not been a panacea for the clay worker. As you would suspect, the more tightly knit column will produce a ware that will vitrify more readily than the unde-aired column. The product is much more difficult to cool in the kilns than is the ordinary clay product. It has meant that frequently changes have had to be made in the drying and firing conditions. Where these changes in operation have been made successfully, de-airing is an unquestionable benefit in the manufacture of clay products.

There are some clays which have a tendency to crack in the drying, no matter how slowly they may be dried or under what atmospheric conditions. Often these are clays which are nearest the centers of consumption and constitute a tempting source for the production of common clay products. There are a good many things which can be done to such clays to render them more workable. In recent years the chemists have taught us a good deal about pH control and base exchange in clays. The soils chemists have been especially active in the latter field and have taught us that the character of the soil can be radically changed by the addition of salts which will enter into the constitution of the clay molecule, giving it in some cases very different properties from the untreated clay. It has been the custom for quite some time for our sewer pipe manufacturers to add salt to their batch, realizing that the clay worked better in the die and that it had less tendency to crack in the driers.

We had experience with a very unmanageable clay. This clay was of a windblown type so common in the Southern States. Several plants had demonstrated that it was impossible to make a marketable product for any considerable length of time using the untreated clay. The cure turned out to be the addition of a small amount of acid which flocculated the clay, making it decidedly more plastic. With this procedure it was possible to dry and fire the clay safely. Recently it has been found that an accurate control of the clay is a contributing factor in working the common clays.

Recently a great many reagents have come on the markets which can be used to advantage if the character of the clay is known and if technical knowledge is applied. Several of these reagents, such as the sulfonates, increase the rate of penetration of water into the clay body and are called penetrating or spreading agents. There is quite a difference of opinion among physical chemists regarding film formation, but whatever the explanation is, it has been found possible to use these reagents to advantage with many clays while they are useless with others. A recent outstanding example was the tendency of a clay to set up on the walls of the brick machine to such an extent that the die had to be removed and the barrel cleaned every few hours. The addition of a penetrating agent caused the water to seep through this hard cake, causing it to soften and loosen from the barrel.

There are a great many reagents, such as alkaline starch solution, "plasticade", ammonium alginate, and the aluminates, which tend to make certain clays much more workable and which either shorten the drying time or make the clays dry more safely. They usually affect the dry strength of the clay.

Ceramists have learned in recent years that clays are not unalterable bodies which must be used in the form in which they occur. It was formerly thought that clays were clays, and some of them could be used while others could not. There was a sort of superstition against the attempt to alter the properties of a clay. This has all passed, and the clay men are learning to work themselves out of their difficulties and are making products which were formerly unheard of with certain unmanageable clays.

A few years ago it was thought possible to beneficiate the secondary fire clays of Ohio in such a way that they could be used for the whiteware industry. These clays had been used for generations in the stoneware industry with success. They have the properties of a kaolin and a ball clay combined. They have an excess of silica which is not objectionable except in some cases; the grain size is quite acceptable to the stoneware industry. The principal objection to these clays was the fact that they contain a considerable amount of iron and that a portion of this iron appears as specks in the final ware. The thing which led us to consider their use had to do partly with the fact that most table ware is now made in cream and ivory shades. The fire clay would, of course, be off-color for a white product. With this general idea in mind, Dr. Shaw, with considerable advice from the Battelle Institute, went to work on the problem, and after trying electromagnetic, electrostatic, air separation, and wet flotation methods, finally in desperation tried the long-discarded film flotation method used in conjunction with a McQuistin tube. This method consists of running the slip through a rotating, partially immersed tube set at an angle. Various oils are used, such as kerosene and creosote. The iron specks are brought to the surface, forming a film on the water from which it is skimmed. I believe you can see the logic of the thing when you consider the small amount of material which was removed and the large amount of clay-like substance which we wish to recover. The proposition is just opposite from the usual demands of the flotation engineer. We found that the method worked beautifully in the laboratory, but have yet to persuade someone to put in the equipment required.

The dinner plates made from the cleaned clay at two or three of our potteries were entirely devoid of specks, and the clay had certain properties which seemed to make it a possible addition to the whiteware batch in small amounts.

Speaking of the further possibility of beneficiating the common clays, I should guess that it would depend upon future research work. If a clay by purification can be made to provide the raw material for a product of a higher order, as for instance, using our fire clays in the pottery industry, it is entirely likely that a reasonable price could be paid for beneficiation. If a refined clay could be used to produce a better product in the same field, such as the removal of the alkalies from a fire clay to produce a better refractory, the beneficiation would pay if the cost were not too high.

Whether the price of beneficiation can be absorbed would depend entirely upon the price received for the product made. A German plant which I visited was washing pebbles and iron concretions from their clay for the fabrication of roofing tile while they were using the clay as harvested for their common bricks because it was too expensive to clean the clay.

CONCLUSION

The matter of beneficiating a clay is a research problem. Methods, processes, machines are the things required, and we can go no further until we have them. If enough benefit is derived from the purification or alteration of the clay to pay for the costs involved, then we can expect beneficiation in a given field. If the costs exceed the benefits derived, then there will be no further beneficiation. The incentive to act involves the profit and loss sheet of anyone contemplating beneficiation.

NEW DEVELOPMENTS IN THE PROCESSING AND FORMING OF CLAY PRODUCTS

By

R. K. Hursh

Professor of Ceramic Engineering, University of Illinois; and Secretary, Illinois Clay Manufacturers' Association

New developments in an industry that antedates written history cannot be expected to be of a radical or revolutionary character. The steps of progress are like stairs of low rise and broad tread. Change is gradual and is represented essentially by minor modifications of equipment and methods that lead to more efficient plant operation and lowered unit cost of production.

The raw materials must be taken essentially as nature has produced them. Modification of their physical and chemical properties is limited. Careful selection of the materials and control of the properties of the product by mixture of clays and by physical methods of preparation are receiving increasing attention by the manufacturers.

There is little that is new in the basic methods of manufacture of clay products. The clay is taken as it is found, tempered with water, formed into shapes that are dried and fired. Thus were the bricks made for the construction of the temple in Babylon. But the equipment used in these processes has been greatly changed and, of greater importance, methods of control of the processing and of the quality of the product have been developed. The changes have been a slow but certain evolution. It has been said that "the invention of the wheelbarrow was the most important step in the development of the brick industry." The wheelbarrow is still an important piece of equipment in the plant but it is a very different machine and the industry is fairly well out of the wheelbarrow period. When one views the conveying and transportation equipment of the modern plant, even "the horse and buggy days" seem to be well behind.

Pit operations have undergone progessive change from hand digging to the use of a variety of forms of mechanical excavators. The steam shovel has been greatly improved in flexibility and efficiency of operation by the change from the locomotive type to the caterpillar type, with a great reduction in the number of men required in its operation. Electric shovels and gasoline-electric equipment has, to a considerable extent, replaced the steam shovel. The drag-line excavator has been found an advantageous type of machine for digging clay because it operates from the top of the bank and, in many cases, performs the combined service of stripping and loading. Operating with a sloping face, difficulties from caving of the bank are decreased but its service is limited generally to excavation of material that is not so hard as to require blasting. In England, there seems to be considerable use of a bucket and chain type of excavator that operates from the top of the bank and delivers the clay to continuous belt conveyors, eliminating car haulage. This type of machine does not seem to have found a place in clay plants in this country although it is used somewhat in the digging of canals and in irrigation projects. It lacks some of the flexibility of the shovel and dragline and is not well adapted to operations requiring selection of clays or where different materials are separately dug for mixing in required proportions at the plant. The shale planer is a near approach to this machine but operates from the bottom rather than the top of the bank.

There has been considerable development in respect to the selection of materials and mixing of different clays in definite proportions for control of the working properties and color of the fired product. Separate digging of different strata in the same pit and mixing of materials from different localities has required the installation of storage bins together with mechanical proportioning equipment. The disc feeder and several types of continuous weighing devices have found extensive use. In the face brick plant, where a variety of mixtures may be required for different color effects, and in plants where uniformity of the product requires careful selection and proportioning of two or more materials, the batch-house and mixing equipment are finding more extensive adoption.

In the grinding of clays and shales, the dry pan has retained its place as the most favored type of equipment. There has been a trend, however, to much heavier machines with increased capacity and lower costs of maintenance. Greater crushing capacity has been sought by use of wider and of heavier mullers and these, of course, necessitated heavier construction throughout the machine. In one type of dry-pan an increased crushing force and adjustment to suit the material handled is obtained by use of hydraulic jacks or rams which apply a downward pressure on the muller shafts and produce the effect of heavier mullers.

The most notable change in drypan design is, perhaps, the "so-called" grinder. The usual screen plates are replaced by an adjustable slot around the edge and inside or below the fixed rim of the pan. Instead of dropping through the openings in the floor of the pan as it is thrown out centrifugally to the side, the crushed material passes through this slot under the rim. The slot opening is adjustable but is generally larger than the screen plate slots that are normally used in dry pans. As a result, there is a much higher proportion of coarse material in the grinder product and the maximum particle size is greater. The load on the screens to which the material is fed is thereby increased and a larger amount of material is rejected and returned to the grinder. It is claimed that, by removal of the fines as fast as they are produced, the capacity and crushing efficiency of the machine are increased. It functions primarily as a grinder and the operation of sorting or sizing the product is left entirely to the screens.

Precrushing of the lump material before delivery to the pulverizing machine has materially improved the efficiency and capacity of the grinding department. Crushers to reduce the lumps of clay to two- to four-inch size are extensively used.

Irregular and uneven feeding of material to crushing and grinding machines has been eliminated, in many cases, by installation of plate or apron feeders. By adjustment and control of the rate of feeding the crushing and grinding efficiency may be maintained at a maximum and, where the ground product goes directly to the forming machine, the entire plant operation can be kept in step.

The vibrating type of screen has been quite generally adopted, replacing the gravity screen. It is capable of a higher rate of screening per unit area and, therefore, takes up considerably less height and floor space in the plant. Less attention is usually required to keep the screen cloth clean although wet clays are likely to give considerable trouble from blinding of the screen.

The vibration may be applied either to the frame of the screen or to the screen cloth itself. In some cases, the vibration of the cloth is produced by an eccentric and the amplitude may be adjusted by the setting of the eccentric. Unbalanced pulleys may be used to give a more or less elliptical movement of the screen cloth. Cams or toothed wheels give a jarring movement in other types and hammers may be used to periodically strike the screen or an anvil attached to it. In the case of the electrically operated screens, a floating solenoid, attached to the screen cloth, is caused to vibrate by current of regulated frequency passed through the windings of an electro-magnet.

The efficiency of operation of the vibrating screen is affected by the type of material handled, the range of particle size in the feed, and by the rate and method of feeding. It has been stated that, for good operation, the depth of the material on the screen should be reduced to a thickness of one particle by the time the material has passed over one-third the length of the screen. Otherwise, it is likely that some of the fines will be carried over in the tailings. For effective operation, the slope of the screen, the amplitude of vibration and the method and rate of feeding should be adjusted to suit the particular type and characteristics of the material which is to be handled.

Some further attention to details in grinding and screening practice would, in many cases, undoubtedly result in more effective and efficient operation. Screen analyses of the grinder product, of the screen product and of the tailings furnish means of determining the proportion of fine material produced by the grinder that is separated by the screen, as well as the ratio of the weight of material fed to the screen to the weight of product. These values provide considerable information as to the efficiency of the plant and a basis for consideration of changes that may effect improvements in the operation.

In the preparation of wet or moist clays there has been a decided trend to finer crushing to obtain a more homogeneous material and, more particularly, to break up the small pebbles that are common to the surface clays. A disintegrator of the pug-mill type is generally used for the preliminary treatment. From this the clay goes to conical rolls which are effective in separating the larger stones and then to smooth rolls for the fine crushing or grinding. To accomplish finer disintegration with this equipment, an additional set of rolls has been provided in many installations. Better and more uniform results than those of previous practice are also being secured by more careful maintenance of a single set of smooth rolls. These may be refaced at frequent intervals by a grinder attached to the frame of the crusher so that removal of the rolls is not required. The total life of the rolls has been considerably increased in some instances by this practice.

In the tempering and forming of structural clay products de-airing has been a significant development and has been the subject of much discussion. Random experiments were made with de-airing many years ago and some of these with considerable apparent success. But general interest in it and wide-spread adoption is comparatively recent. Like most developments in mechanical equipment it has not fulfilled all of the expectations or desires. In some applications where it has been tried the results have not been satisfactory. But de-airing has so proven itself as an advantageous feature in the processing of structural clay products as well as in other applications that its value is beyond question.

De-airing treatment of pugged clay in the brick machine was developed primarily as a means of eliminating laminations in the product. The slippage of layers of clay as it moved through the machine and die, or differential flow, was attributed largely to the lubricating effect of air entrained in the mass. By evacuation of the air this difficulty, it was thought by many, would be overcome. However, it was not to be expected that de-airing would entirely prevent differential flow nor insure complete rewelding of the clay at the resultant slippage planes. The treatment does materially reduce lamination, so much so that many clays show no evidence of this fault in the product.

Probably the most valuable result of de-airing treatment is the increase of cohesion, toughness and strength of the clay body. Some materials which could be used only with difficulty in stiff-mud molding can now be formed readily with de-airing equipment. The plastic strength is so increased that larger and more difficult shapes can be made and handled with ease. A further important gain is in the elimination of blistering of the clay column as it leaves the die.

The experience with de-airing in relation to power requirements seems to vary considerably. Some report no difference, some find an increase in power needed, while some have reported an increase of production with a lower power consumption than without use of de-airing. In most cases, the observations are unquestionably matters of opinion rather than results of actual measurements. Conditions and materials vary so widely, however, that it would be unsafe to draw general conclusions without some extensive investigation and actual determinations of power used under operating conditions. It is not to be expected that the same machine should be equally effective with clays of different characteristics and working properties nor that the same general equipment should serve equally well with de-aired and with nonde-aired clays. However, there has been a rather general tendency to apply de-airing treatment with little or no consideration of modifications in machine and die design that might be best adapted to the changed characteristics of the clay body. Much more attention will be required in this direction.

Even prior to the advent of de-airing much attention was given to the lamination problem and hence to the design and construction of the dies that shaped the ware. Most of the efforts in this direction have been devoted to the solution of a particular plant problem and little information concerning procedure and results has become generally available. The results of several investigations in both plant and laboratory on die designs and the effects of various combinations of augers, spacers and dies for brick and hollow ware have been published. Such compilations of data and experimental results should contribute much to improved design and better adaptation of equipment to specific conditions and problems in the formation of clay products.

The application of de-airing treatment has not been confined to stiff-mud operations but has found definite use in dry pressing as well. While dry pressing is applied much more extensively in the production of refractories than for structural clay products, its possibilities deserve consideration. Several methods have been suggested and tried but evacuation of the mold box seems to be most adaptable in industrial practice. By this treatment the density and strength of the body is considerably increased and the porosity is decreased.

The drying of clay products has been a subject of a good deal of study and investigation in the past few years. A considerable amount of information has been obtained concerning the physical processes involved in the movement of water in the clay body and the effects of variation in the drying conditions. Two rather distinct stages in drying have become evident. Shrinkage accompanies the removal of water during the first stage and the rate of water loss may be considered to decrease linearly during this period. The rate of water loss is directly dependent on the drying conditions—the temperature, relative humidity, and velocity of air movement. When the moisture concentration at the surface of the article reaches a point at which no further shrinkage can occur, the vaporization of the remaining water occurs within the body. From this point, which may be termed the "critical point", the rate of loss decreases with a curvilinear relationship to time and the rate is determined largely by the structure of the clay body rather than by the external conditions. The first stage, the shrinkage period, is of primary importance from the standpoint of safety in the drying of clay products. Stresses may develop with rapid drying that cause cracking or permanent distortion of ware and the drying rate must be regulated by proper control of the atmospheric conditions in the dryer.

De-airing has introduced new drying problems in many industrial dryers. The greater density and the change of structure of the clay body retard the rate of water loss so that a longer drying period may be required. Slower drying in the shrinkage period may be offset by speeding up the later stage by increased drying temperatures but a definite knowledge of the drying behavior of the ware and means of control of the drying operation are essential to satisfactory results.

To a great extent, faulty operation and unsatisfactory results in dryers are due to lack of regulation and control of air movement. A number of dryers have been built and old dryers modified with the objective of better air distribution and a positive circulation through the ware setting. In some of these a number of circulating fans are arranged at different points along the length of the dryer to take air from the top of the tunnel and return it underneath the ware. A combined cross flow and longitudinal flow is thus secured. Temperature and humidity control devices can be provided to separately regulate drying conditions in the various sections.

In order to maintain a high drying rate in the hot end of a progressive tunnel dryer and more moderate conditions in the cooler section, provision is made in some cases to draw off part of the hot air midway along the tunnels and thus reduce the quantity of air passing over the ware in the early stage of drying. A somewhat similar plan is used in another installation. Here a vertical air circulation is maintained in the hot end by admitting the hot air through a series of floor ports and withdrawing part of the air through exhaust ports in the roof. The air returns to the intake of the pressure fan and is again delivered to the dryer. By thus recirculating part of the air in the hot end, a higher velocity can be maintained with faster drying as a result. At the same time, the moisture content of the air is increased sufficiently to afford moderate drying conditions for the entering wet ware which is inclined to crack in the early stages of drying.

Improvement in control of drying conditions has also been sought through regulation of the quantity of air furnished by means of variable speed drives for the fans. Variation of the fan intake opening by means of dampers is another means of controlling the air supply. Admixture of cold air to the hot air from the cooling kiln, in order to regulate the temperature in the dryer, is secured by a thermostatically controlled air shutter or damper.

In connection with firing operations, regulation of kiln atmospheric conditions and temperature has received increasing attention. Fuel requirements have been decreased, the firing period has been reduced and better control of the color and quality of product has been secured in many plants. New firing technique has been developed, in a number of cases, to produce new color effects through flashing treatments or use of zinc or other coloring agents.

The introduction of the continuous car-tunnel kiln in structural clay products industries has been slow. A number of such kilns have been in successful operation for brick and similar products for a considerable period of years. Several installations have recently been made, some with unusual features, and the results of these are being watched with great interest. The firing of many glazed products has been especially satisfactory in the car-tunnel kiln. The availability of gas as a fuel has been particularly advantageous in this application. It is to be expected that more extensive use of this type of continuous kiln will develop in the structural clay products field.

The interest in and demand for a variety of color effects in brick and similar products has materially increased the use of glazes. The application of these has been facilitated by passing the dried ware on continuous conveyors through spraying booths. Other surface effects are produced by application of colored sands or dry facing mixtures by various methods. A sandblast is used in some cases to blow the particles into the surface of the green ware. Another method, introduced from England, applies the color by stippling the surface of the brick column and forcing the granular coloring material into the surface with steel wire brushes.

New forms and types of product have been developed in recent years. Interest in reinforced masonry has resulted in a considerable variety of special shapes adapted to use with reinforcing steel bars in the mortar. The objective is, in most cases, the preforming of slabs or beams before placing them in the structure. Tiles of various sorts for wall facing have been produced, some for attachment as a veneer, some to be used in precast slabs. Light-weight structural products of many forms and types have been introduced. One of the objectives is an easily handled unit of larger than brick size. Acoustic material for reduction of noise is another important objective. Thermal insulation material and products have been in such demand that much effort has been devoted to produce a structural unit to meet the need.

Most of these new forms and types of clay products must be considered as still in the development stage but some very definite and, perhaps, radical changes or additions in the field of structural clay products may be anticipated as a result of the research and experimental work that is in progress.

SYMPOSIUM ON INDUSTRIAL MINERALS

UNEXPLOITED OR LITTLE KNOWN INDUSTRIAL MINERALS OF ILLINOIS

By

J. E. Lamar

Geologist and Head, Non-fuels Division,
Illinois State Geological Survey

INTRODUCTION

Throughout the State of Illinois are scattered a variety of minor industrial minerals, most of which are unexploited and many of them not generally known. None of these resources as now understood are conceived to be the basis for an extensive mineral industry. However, some of them may be sources of additional revenue for certain of the State's mineral industries, which by reason of technical knowledge, geographic location, or business relations, are able to profitably exploit one or more of these resources.

The data presented are an accumulation of thoughts and observations rather than the results of an intensive study of the resources described. Probably some of the resources to be described and their utilization might well be made subjects of research by the Survey were not other projects of greater general significance and more widespread application occupying attention. Despite the fact that the data at hand are limited, it does seem worth while to point out these resources for the information and possible benefit of the Illinois mineral industry.

For many of the resources, those uses which have thus far come to mind will be suggested, likewise any significant test data at hand will be given. The field is, however, wide open to the ingenuity and resourcefulness of the Illinois mineral industry.

Due to the length and scope of this paper, details regarding many items have of necessity been omitted. Upon request the Survey will gladly furnish any specific data available, and will further be glad to cooperate in any way possible within its legitimate field with those of the Illinois mineral industries seeking to develop uses for these resources.

POTASH

The potash-bearing rocks of Illinois of possible commercial significance are of two major kinds, shales and greensands. In the latter the potash is probably present mainly as a part of the mineral glauconite, which is essentially a hydrous silicate of ferrous iron and potassium. The mineral is green in color, hence the name greensand for sands rich in glauconite.

Several articles have been published regarding potash in Illinois,[1] one of which deals with potash as a by-product from the shale used in cement manufacture. It is not proposed to consider this particular angle here, but rather to discuss potash-bearing rocks, with reference to their possible use as fertilizer, reviewing briefly the published data and adding recently obtained unpublished information.

SHALE

A potash-bearing shale, the Mountain Glen formation, 35–45 feet thick, outcrops at a number of places in Union County (fig. 1). Several deposits favorable with respect to quarrying conditions and railroad transportation have been described. This shale has an average K_2O content of 5½ per cent and appears to be quite uniform with respect to potash content. Sixty-two per cent of the potash in a sample studied in detail was removable by extraction with sulfuric acid and pot culture tests indicate that the acid extractable material is largely responsible for the fertilizing value of the shale. A series of greenhouse pot culture tests were made in which various combinations of lime with kainit, alunit, leucite, and Mountain Glen shale were employed. The results of this work led to the following conclusions: "The pot culture work in the greenhouse indicates marked benefit to crops resulting from application of shale. The results are so striking and of such possible economic development as to warrant more extended investigations, particularly in the field. It is quite evident that the potassium in this shale can be directly used by crops in pot cultures under greenhouse conditions."[2] No commercial exploitation of this shale has occurred to date.

GREENSAND

Deposits of greensand have been observed in the vicinity of Olmsted[3] (fig. 1) in southern Illinois. The exact thickness of the deposits is not known, but a 4-foot greensand bed separated from another 3½-foot bed of greensand by 1 foot of conglomerate has been reported to outcrop in sec. 13, T. 15 S.,

---

[1] Parr, S. W., Austin, M., Krey, F., and Stewart, R., Univ. Illinois Agr. Expt. Sta. Bull. 232, 1921.

Schroyer, C. R., Notes on potash possibilities in Illinois: Illinois Geol. Survey Bull. 38, pp. 434-436, 1922.

Schroyer, C. R., Potash as a by-product in cement manufacture: Illinois Geol. Survey Bull. 38, pp. 437-440, 1922.

[2] Parr, S. W., et al., Univ. Illinois Agr. Expt. Sta. Bull. 232, 1921.

[3] Schroyer, C. R., Notes on potash possibilities in Illinois: Illinois Geol. Survey Bull. 38, pp. 434-436, 1922.

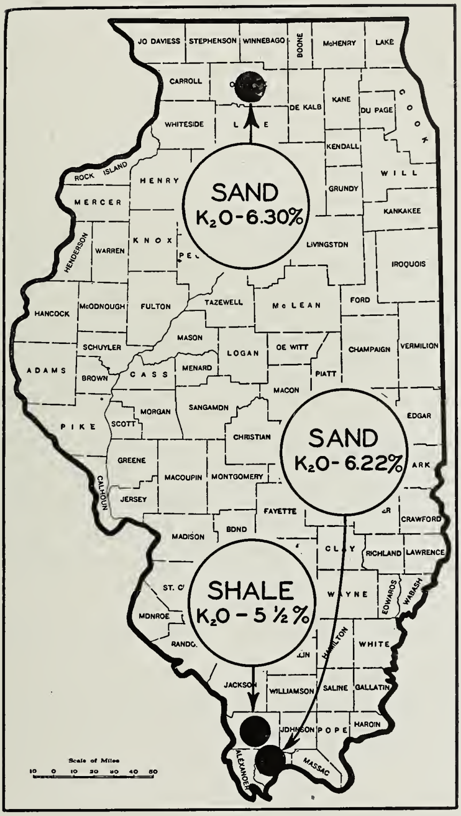


FIGURE 1.—Potash shale and greensand deposits in Illinois.

R. 1 E. This deposit analyzed 6.22 per cent K_2O, most of which probably was present as a constituent of the mineral glauconite. Detailed search may reveal other deposits of greensand in southern Illinois of sufficient size and having thin enough overburden to be workable on a moderate scale, but in general a thick, unconsolidated overburden is likely to be found on most deposits.

About one-half mile northeast of Oregon, Illinois (fig. 1), in the S. ½ N. ½ E. ½ sec. 3, T. 23 N., R. 10 E., there is exposed in what appears to be an old quarry a glauconite sandstone known as the Mazomanie formation. This is the only outcrop of this formation in Illinois, and it appears to have resulted from sharp folding or faulting of the bedrock or possibly both. Ten feet of the sandstone is exposed, but its total thickness is probably much greater than this. It is a fine-grained, brown, thin-bedded sandstone that is easily reduced to a sand. A count of 1,000 grains of the sand after washing to remove clay, showed 12 per cent of glauconite grains. A chemical analysis of the raw sandstone reported 6.30 per cent K_2O. The amount of sandstone which could be quarried by open pit methods is probably small, but as the sandstone is overlain by a dolomite formation, a good roof probably would be available for underground mining. The possible effects of structural conditions on such a procedure would require thorough investigation.

The Glenwood sandstone, which also outcrops at many places near Oregon and lies above the thick St. Peter sandstone formation of that region, is likewise glauconite in places. No deposits have been reported which have a glauconite content comparable to that of the other greensands described, but careful search might reveal such deposits.

Probably the best known greensand deposits in the United States are those occurring in New Jersey. The K_2O content of these sands varies between 5 and 7 per cent.[4] Attempts have been made to extract the potash from the New Jersey deposits, but so far as is known were unsuccessful commercially. However, the possible use of raw greensand as a potash fertilizer material[5] should not be overlooked. It is reported[6] that New Jersey greensand is spread on the soil in its raw state as a fertilizer and that Virginia greensand is dried and ground for use in commercial fertilizers.

COARSE-GRAINED AND FINE-GRAINED SANDS

Sands of various types are widespread throughout Illinois. In the northern part of the State glacial or related sands, most of them calcareous, are abundant and in this area likewise occur the unexcelled silica sands of the St. Peter formation. Sand is also abundant along Mississippi, Illinois and Wabash rivers and adjacent areas; some of it is calcareous, most of it is not high silica sand. In Alexander, Pulaski and Massac counties of extreme southern Illinois, sands of an entirely different age than those mentioned are to be found in deposits of considerable thickness and extent. Mostly the sands are medium or fine grained but in Alexander County coarse sand is also present. In view of the possible commercial significance of these coarse sands and very fine sands, a brief discussion of the Alexander County sands is given.

DESCRIPTION OF DEPOSITS

Near the center of the south line, SW. ¼ sec. 22, T. 15 S., R. 3 W., near Thebes, 16 feet of coarse sand is exposed in a hillside behind a farmhouse. Below the sand lies 16 feet of interbedded fine sand and clay and above it a variable thickness of brown clayey silt. There is a thin layer of chert gravel about 12 feet from the top of the sand deposit. The sand is red in color due to a coating of red clay on the grains. When washed free of the clay about 5 per cent of the sand grains are seen to be chert and the remaining 95 per cent are almost entirely quartz. Some of the quartz grains are clear and transparent, others are of the milky variety. The shapes of the grains vary from angular to rounded and all grains exhibit more or less polished surfaces. Sample 61, table 1, was taken from this deposit, which is about 1½ miles by road from two railroads and the Mississippi River.

---

[4] Schroyer, C. R., Idem, p. 436.
[5] Ladoo, R. B., Non-metallic Minerals, p. 444, 1925.
[6] Ries, H., Economic Geology, p. 279, 1930.

Another deposit of a roughly similar nature occurs on the top of a ridge in SE. ¼ sec. 27, T. 15 S., R. 3 W. near Fayville. Seventeen feet of coarse red sand is exposed in an old gravel pit. Overburden is chert gravel and clayey silt but the nature of the exposure did not permit worth-while estimates of overburden thickness. Sample 42 was taken from the upper 6 feet of the exposure and sample 42A represents the entire 17 feet of sand (table 1).

Fine-grained, high silica sand is exposed at a number of places near Fayville, one of the best of which occurs in an abandoned man-made roadway cut between two valleys in the NW. cor. NE. ¼ NW. ¼ sec. 34, T. 15 S., R. 3 W., where 35 feet of white micaceous sand locally containing thin beds of clay is exposed beneath about 25 feet of brown clayey silt. The deposit is about ½ mile from two railroads and Mississippi River. Sample 300 was taken from the sand.

Twenty feet of similar white sand is exposed along the wagon road in the cen. SE. ¼ of the same section and sample 41 represents this deposit. The deposit is located along a railroad and is only a short distance from Mississippi River.

TABLE 1—RESULTS OF SIEVE TESTS ON ALEXANDER COUNTY SANDS
(The sieve test of St. Peter sand from the Ottawa district is included for comparison.)

Sieves	Coarse sands			St. Peter sand	Fine sands	
	No. 42A	No. 42	No. 61		No. 41	No. 300
—4 + 6 mesh.....	1.1	0.5	0.0	....	....	....
—6 + 10 mesh.....	3.1	3.0	2.3	0.0	....	....
—10 + 20 mesh.....	19.8	27.0	32.3	0.4	....	....
—20 + 28 mesh.....	29.9	26.0	31.3	18.3	0.0	....
—28 + 35 mesh.....	19.9	16.4	15.7	52.5	0.1	....
—35 + 48 mesh.....	8.7	12.1	4.3	19.2	0.5	0.0
—48 + 65 mesh.....	4.1	4.0	2.6	4.9	3.9	2.0
—65 + 100 mesh.....	2.2	1.9	1.5	2.7	57.1	17.6
—100 + 150 mesh.....	0.3	0.2	0.2	1.2	21.7	20.4
—150 + 200 mesh.....	....	....	....	0.5	8.8	34.4
—200 + 270 mesh.....	....	....	....	0.1	1.9	11.6
Pan..................	0.2	0.2	0.3	0.1	0.6	9.8
Clay.................	10.5	8.5	9.6	0.6	4.7	4.2

USES OF SAND

Laboratory washing tests on the coarse sand shows that most of the clay associated with it is removable without difficulty giving rise to a light pinkish-colored sand. It would seem likely, therefore, that a commercial washing process, such as that used in the Ottawa district, would yield a product suitable for some of the physical uses of silica sand. However, it is doubtful if simple washing would yield a product suitable for most chemical uses of silica sand. The outstanding character of the sand is its coarseness, its non-calcareous nature and high silica content. So far as is known, the sands described are the coarsest quartz sands in Illinois. Compared with a sample of silica sand from Ottawa it is seen that whereas the Ottawa sand contains 0.4 per cent material coarser than a 20-mesh sieve, the southern Illinois sands have 24, 30, and 35 per cent plus 20-mesh material. Likewise, a figure of 19 per cent coarser than 28 mesh for the Ottawa sand is to be compared with figures of 54, 57 and 66 per cent for the southern Illinois sands. Figure 2 presents some of these data graphically.

While further testing is necessary before specific uses can be recommended, it is suggested that the sand is worthy of consideration for sand blast sand, filter sand, and probably other uses. Whether the deposits are of suitable character and of sufficient size to warrant commercial exploitation cannot be stated on the basis of the data available from the natural outcrops; however, it is believed the chances are good that detailed exploration will reveal commercial deposits.

The fine-grained sands are composed, exclusive of their clay content, of about 96 per cent quartz, 3 per cent white mica, and 1 per cent other minerals. Laboratory washing gives rise to a white sand except for small amounts of yellow iron-cemented clay grains. Probably scalping over a 65-mesh sieve would remove most of the clay pellets and one-third of the mica. Washing also offers an opportunity to eliminate clay and a considerable portion of the mica. The latter may be marketable.

Sieve tests on two samples of the fine-grained sand are given in table 1, which shows, excluding clay, 33 per cent finer than 100 mesh for one sample and 76 per cent for the other.

The fine-grained sands may have a number of uses but the only one which has been investigated thus far is molding sand. Results of a molding sand test made in the Foundry Laboratory, University of Illinois, are as follows:

> Am. Foundry Men's Assn. Grain fineness No. — 20
> Cohesive strength—100
> Permeability—38
>
> This sand is very good in fineness, permeability and refractory qualities, but the bond or cohesive strength is low. The bonding material is also short lived. As found in nature the sand would have a small use in core sand mixtures; if the cohesive strength were raised by adding about 2 per cent of plastic clay, it could be used for heavy brass castings.

> If the sand were treated to remove mica and clay and then were used with an artificial bond, it would be a good molding sand for brass, aluminum and small cast iron castings and also a good core sand for general purposes.

The statement previously made regarding commercial deposits of coarse sand applies as well to the fine-grained sands.

PEAT

The peat deposits of Illinois occur mainly in the north half of the State and in Tazewell and Mason counties in the central part. Although the peat resources of Illinois have not been studied in detail, it has been estimated that in the 6 counties thought to contain the largest deposit of peat—DuPage, Kane, Kankakee, Lake, Tazewell and Winnebago—over 42,000 acres of peat are present which would yield about 10,000,000 short tons of air dried peat.[7] In general most of the deposits are comparatively small but a deposit in Cattail Slough near Sollers in Whiteside County is estimated to contain nearly 4 million tons of air dried peat, a deposit near Manito in Tazewell County, 120,000 tons, and a deposit near Antioch in Lake County over 400,000 tons.[7]

The thickness of the peat deposits usually ranges between 5 and 20 feet but deposits as thick as 35 feet are reported. Most of the peats are the result of the decay of grass, sedge or cattail vegetation. No sphagnum moss peat of consequence is known.

Analyses of Illinois peat[8] indicate that in general they contain too much ash to be used as fuel, though they may be used in making fertilizer and packing material. The Illinois peats are in the main relatively impure, however, the average nitrogen content of 18 samples of Illinois peat is 2.65 per cent which is above the general average. Five Illinois samples contained over 3 per cent nitrogen and one from Lake County 3.84 per cent, an unusually high figure for raw peat.

Comparatively small amounts of peat or muck are now being produced in the Chicago district. One of their important uses is lawn dressing. At Manito peat was once produced in considerable amounts as a filler or packing material and for other purposes.

The effectiveness of raw Illinois peat in general as a fertilizer has not been definitely determined but due to its water holding capacity, the peat can be used advantageously for reducing cracking and improving the texture of heavy clay soils. Packing material, filler, litter, lawn dressing and for addition to the soil on greenhouse benches are other possible uses of Illinois peats.

---

[7] Soper, E. K., and Osbon, C. C., The occurrence and uses of peat in the United States, U. S. Geol. Survey Bull. 728, pp. 104, 107, 109, 110, 1922.

[8] Ibid., pp. 27 and 58.

MARL

The term marl is popularly used in Illinois to describe any incoherent deposits consisting principally of $CaCO_3$. Shell marl is one general type of material to which the term is applied and it is likewise used to describe spring deposits. Materials of the latter type have been observed at several places in Calhoun County, in Bureau County, in Fairies Park at Elgin and other places north of the park on the east side of Fox River valley, and near Danville. In general these deposits are small and solely of local significance as sources of material mostly used as agricultural limestone.

The shell marl deposits on the contrary in places may reach considerable size. They are composed of the shells of small fresh water animals together with variable amounts of clay and sand. In general the shell marl deposits lie below peat deposits, although in some deposits the peat is thin. Discovery of the deposits is mainly a matter of chance or of prospecting peat deposits or swampy depressions. In general the marl accumulated in ancient lakes which existed in depressions which are usually still reflected in the present topography and topographic conditions favoring relatively clear quiet lakes might be expected to favor the formation of marl. It is believed that the northern third of the State is more favorable for marl deposits than the southern two-thirds, and that in general marl deposits will be found most commonly in Lake, McHenry, Cook, DuPage and Kane counties.[9]

A brief description of some of the larger known deposits may be of interest. Southwest of Chatsworth in Livingston County a marl deposit is reported[10] to be 40 feet deep and to cover 40 acres. Another deposit near DesPlaines on the Elmhurst Road just north of McDonald Road is said[11] to be 19 feet deep and some 16 acres in extent. A deposit in Phillips Park in Aurora was shown by borings to have a maximum thickness of 30 feet; other borings recorded thicknesses of 13, 16 and 18 feet.[12] A few miles west of Antioch in a bog between channel Lake and Lake Marie in the flood plain of Fox River 6 to 8 feet of marl was encountered in the center N. ½ sec. 3, T. 43 N., R. 9 E.; about 6 miles north of Barrington, 6 to 8 feet of very pure marl overlain by roughly 1 foot of less pure marl is reported; and Lilly Lake south of the town of the same name contains about 20 feet of peaty marl.[13] Further and more specific information regarding marl in Lake and McHenry counties is expected to result from a study of the geology and mineral resources now in progress.

The composition of Illinois shell marls is not known in detail but it seems likely the marls containing over 85 or 90 per cent carbonates may be reasonably common.

---

[9] Ekblaw, G. E., Personal communication.

[10] Pontiac, Ill., "Leader," July 16, 1937.

[11] DesPlaines, Ill., "Times," Aug. 6. 1937.

[12] Powers, Wm. E., Geological setting of the Aurora mastodon remains: Trans. Illinois Acad. Sci., vol. 28, no. 2, p. 194, December, 1935.

[13] Ekblaw, G. E., Personal communication.

Because shell marl is usually easy to dig and requires little if any crushing, it is attractive for the production of agricultural limestone.

SLATE

There are no true slates in Illinois, but there are several types of material to which this term is sometimes popularly applied and it is these which will be discussed briefly. The first and most widespread "slate" is the variety associated with the coal beds of the State, and sometimes called "roof slate." These "slates" in places lie immediately above a coal bed or several feet of other strata may intervene between the top of the coal and the "slate". They are usually black due to a comparatively high carbon content, fine grained, well bedded and break into brittle, thin sheets sometimes of considerable size. They resemble true slate somewhat in appearance and cleavage, but do not have the hardness or weather resistance of true slates. None of the "slates" tested thus far have been calcareous, but many of them contain pyrite, though this is not necessarily a general characteristic.

As has been intimated, the Illinois black "slates" are of Coal Measures age and as many Illinois coals have some "slate" above them, it is evident that the "slates" are widespread. It is impossible to describe all the known Coal Measures "slate" outcrops in Illinois, but a few data will serve to give an idea of their occurrence and thickness. In northern Illinois, the LaSalle No. 2 coal has 2 to 3 feet of black "slate" above it in that part of the area lying west of Starved Rock State Park; east of this place the "slate" is lacking, or inconsequential. Also, in northern Illinois the Springfield No. 5 coal is overlain generally by 2 to 3 feet of "slate." A similar thickness of "slate" lies below the LaSalle limestone in the same general area and likewise 2 to 3 feet of "slate" occurs below the No. 6 coal of the Streator area and is the floor of coal mines.

Four feet of black "slate" is found in places over No. 1 coal north of Monmouth in western Illinois. "Slate" also occurs above the No. 2 coal of western Illinois. In the vicinity of Peoria and Galesburg the No. 5 coal has a "slate" which reaches 4 feet thick.

In Williamson County of southern Illinois the No. 5 coal also has a black "slate" above it in places. The "slate" has a maximum thickness of about 3 feet. Many mines in No. 6 coal in southwestern Illinois locally have 2 to 3 feet of "slate" above the coal.[14]

No special study has been made of Coal Measures "slate" deposits capable of being worked solely as a source of slate. Some such deposits probably exist, but an easier and probably cheaper procedure would be to produce "slate" in conjunction with coal mining.

---

[14] Cady, G. H., Personal communication.

Two other types of slaty shales occur in southern Illinois a few miles southwest of Jonesboro in Union County. One of these is a black or dark brown well bedded shale which splits into thin sheets and the other is a highly silicified, hard shale. Both occur in accessible deposits up to 35 feet thick. The black shale owes its color to carbonaceous matter and is usually not calcareous. The silicified shale is hard, brittle and slaty in appearance, gray to greenish gray in color, and in places is slightly calcareous, but considerable thicknesses of noncalcareous shale are present.

So far as is known no use has been made of the Coal Measures "slates" except as a road material. The black southern Illinois shale is not known to have been used for any purpose, but the silicified shale was at one time quarried and crushed for roofing granules. Its weather resistance is reported to have been unsatisfactory, however, and production was abandoned.

No comprehensive investigation of the above mentioned materials as mineral fillers, particularly as a substitute for slate flour, has been attempted but it appears that such a study might have possibilities. Also worthy of consideration is the possibility that the southern Illinois silicified shale might provide a suitable granule for use in preparing coated roofing chips.

BRINES

At the present time salt (NaCl) is being produced in the Middle West from rock salt mines in Kansas, mines and brines in Michigan and from brines in Ohio. It is not generally known, however, that during the nineteenth century Illinois was an important salt producing state; in fact, for a time the major producer in the Middle West. Salt works existed at Equality, Central City, Murphysboro, St. John, Danville, and probably at other places. The eventual cessation of salt production in Illinois was due to the discovery of stronger brines elsewhere in the Middle West.

The fact that salt making from the relatively weak brines used in Illinois in the nineteenth century could not compete with the production of salt from stronger brines elsewhere should not be interpreted to mean that Illinois does not have brines worthy of consideration. As a matter of fact, it has been only in recent years that any even moderately detailed data regarding Illinois brines have been available. There are now in the Survey files about 300 analyses of Illinois brines, most of which were obtained from oil wells or wells drilled for oil. So far as is known no special search for strong brines has been made in Illinois, so that our knowledge of Illinois brines is really a by-product of information obtained for purposes of the oil industry. Nevertheless, an examination of these data shows much of interest.

TABLE 2—ANALYSES OF BRINES FROM ILLINOIS AND OTHER STATES

(Hypothetical combinations in parts per million

	1	2	3	4	5	6	7	8	9	10	11	12	13
KNO_2	....	5	2	1	2	3	....	....	....	....	....	....	....
KCl	5,525	1,302	6,520	1,493	9,322	709	....	....	....	114	713	....	....
$NaNO_3$	....	....	....	....	....	....	....	....	....	....	....	....	....
$NaCl$	115,200	97,680	68,950	10,770	91,980	30,150	91,595	42,582	87,889	84,300	310,977	234,050	141,000
NH_4Cl	....	854	123	35	138	....	27	9	4	....	....	....	....
$MgCl_2$	10,070	4,789	8,468	20,360	5,055	....	3,695	3,900	4,414	5,590	462	21,200	31,000
$CaCl_2$	35,620	4,643	11,995	400	8,166	....	3,024	125,382	9,400	14,340	1,033	32,900	83,000
$CaSO_4$	1,212	7,752	....	393	3,288	2,375	796	886	280	....	4,857	800	....
$CaCO_3$	64	52	33	467	236	227	71	146	103	....	....	....	....
SiO_2	132	7	12	19	18	19	160	220	120	12	0	....	....
Fe_2O_3	11	11	....	....	....	17	17	143	324	83	0	....	Trace
Al_2O_3	16	14	40	24	22	9	140	1,380	240	....	0	50	Trace
MnO	1	1	....	....	....	1	5	15	5	....	....	....	....
Na_2SO_4	....	....	....	....	....	6,649	....	....	....	....	....	....	....
$(NH_4)_2SO_4$	....	....	....	....	....	43	....	....	....	....	....	....	....
$MgSO_4$	....	....	....	....	....	1,069	....	....	....	....	....	....	....
Non-vol	67	1	....	35	....	29	100	180	80	....	....	....	....
Total	167,918	117,111	96,143	33,997	118,227	41,300	[a]99,641	[b]174,869	[c]102,869	[d]105,198	[e]318,163	289,000	[f]256,000

[a] Includes $Ca(NO_3)_2$-11 parts per million.

[b] Includes $Ca(NO_3)_2$-26 parts per million.

[c] Includes $Ca(NO_3)_2$-10 parts per million.

[d] Includes $MgBr_2$-155 parts per million; $SrCl_2$-257 parts per million; $BaCl_2$-343 parts per million; NaI-4 parts per million and LiO_2-trace.

[e] Includes $MgBr_2$-12 parts per million; $SrCl_2$-89 parts per million and LiO_2-trace.

[f] Includes bromine-1000+ parts per million.

1. St. Peter sandstone; J. R. Middagh well, near Lawrenceville, Lawrence County, Illinois; depth 5,185 feet. No oil associated with this brine.
2. Carper sandstone, Lower Mississippian; S. McClelland well No. 1, near Martinsville, Clark County, Illinois; depth 1,400; oil well.
3. Carlyle sand, Devonian; M. Smith; near Carlyle, Clinton County, Illinois; depth 2,620; oil well.
4. Biehl sand, Lower Pennsylvanian; Price No. 2, near Allendale, Wabash County, Illinois; depth 1,480; oil well.
5. Carper sandstone, Lower Mississippian; S. McClelland well No. 2, near Martinsville, Clark County, Illinois; depth about 1,400 feet; oil well.
6. Biehl sand, Lower Pennsylvanian; Widmer Oil Company, well No. 4, near Allendale, Wabash County, Illinois; depth 1,210; dry hole.
7. "McClosky sand," Ste. Genevieve formation, Lower Mississippian; D. Smith, well No. 7, near Clay City, Clay County, Illinois; depth 2,633 to 2,648 feet; oil well.
8. "McClosky sand," Ste. Genevieve formation, Lower Mississippian; Arbuthnot No. 3 well, near Noble, Richland County, Illinois; depth about 2,950 feet; oil well.
9. Benoist sand, Bethel formation, Upper Mississippian; Merryman No. 1 well; depth 1,391 to 1,418 feet; oil well.
10. Coal Ridge Salt Works, Pomeroy, Ohio; Conemaugh formation (Pennsylvanian). Ohio Geol. Survey Bull. 8, p. 27, 1906.
11. Artificial brine, Cleveland, Ohio, H. Ries, "Economic Geology," 1930, p. 222.
12. North American Chemical Co., Bay City, Michigan. Depth 970 feet; upper Marshall sandstone (Mississippian). Michigan Geol. and Biol. Survey Pub. 15, Ser. 12, p. 59, 1914.
13. Midland Chemical Co., Midland, Michigan. Depth about 1,300 feet; upper Marshall sandstone (Mississippian). Michigan Geol. and Biol. Survey Pub. 15, Ser. 12, p. 59, 1914.

Table 2, analyses 1 to 9, shows the composition of some of the stronger Illinois brines. Analysis 1 is the highest on record in NaCl and second highest in $CaCl_2$; No. 2 is the highest in $CaSO_4$; No. 3 is the third highest in $CaCl_2$; No. 4 is the highest in $MgCl_2$; No. 5 is the highest in KCl and also quite high in $CaCl_2$; No. 6 is the highest in $NaSO_4$; No. 7 from the new Clay City oil field is quite high in NaCl; No. 8 from the new Noble oil field has the highest recorded $CaCl_2$ content; and No. 9 from the new Patoka oil field is moderately high in NaCl. Samples 10 and 11 are brines from Ohio and 12 and 13 are from Michigan.

In general, it is believed that the most important constituents of the brines under discussion are NaCl, $CaCl_2$, $MgCl_2$ and bromine. The Michigan and Ohio brines contain bromine; in general, most of the Illinois brines thus far examined contain very little, if any, bromine,[15] though one analysis showed 78 p.p.m. of NaBr according to hypothetical calculations. No intensive search for bromine-bearing brines has been made in this State, however, so that the data at hand are not conclusive.

Disregarding bromine content, it is interesting to compare some of the Illinois brines with the out-of-state brines reported in table 2. Sample No. 8 which is an artificial brine presumably produced by pumping water into and then out of a salt bed, is not fairly included in the comparison. As figure 3 shows, Illinois brines compare fairly well with the other brines. The outstanding brine is No. 1 which comes from the St. Peter formation in Lawrence County at a depth almost 5200 feet. Unfortunately no data regarding the quantity of brines available from Illinois wells is available but there is reason to believe that an adequate quantity may be expected at least from certain formations.

Illinois is at present experiencing a new oil boom which is accompanied by the drilling of numerous wells in regions where no wells or only a few wells previously existed. Unexplored water-bearing strata will be tapped, probably the St. Peter formation mentioned above will be penetrated at a number of places. Insofar as it is possible, the Survey will continue its brine sampling and analysis, with the hope that even stronger brines than any thus far known will be discovered. In the meantime the data at hand is worthy of thought and attention, particularly in its relation to the possible success of a special search for stronger brines in Illinois.

GYPSUM AND ANHYDRITE

Gypsum and anhydrite are two minerals which are closely akin in chemical composition, the difference being that gypsum is calcium sulphate plus two molecules of water, whereas anhydrite is calcium sulphate without chemically combined water. The water which the gypsum contains can be driven off by proper heating and the burned material when wetted again takes up water to give a compound having the original gypsum composition. This last is the familiar action which occurs in the setting of plaster of paris.

---

[15] Rees, O. W., Personal communication.

Anhydrite, since it contains no moisture, does not possess the properties of gypsum just described. Consequently it has not been a widely used mineral. Due, however, to the fact that it is often found in large amounts associated with gypsum, a considerable amount of research has been devoted to a search for major uses for this material, particularly in the field of building materials. Successful research in England resulting in the commercial manufacture of a finish coat plaster, partition tile and "fine aggregate walling" has been reported recently.[16] Further research may soon broaden considerably the field of usefulness of anhydrite.

The existence of deposits of gypsum and anhydrite in Illinois is not generally known; however, considerable thicknesses of these materials are present in places in the area shown in figure 5. The minerals occur in the upper part of the St. Louis formation at depths of 700 to 1,200 feet or less. Unfortunately most of the data regarding gypsum and anhydrite comes from churn drill records which do not permit accurate evaluation of thicknesses. However, several diamond drill cores are available which give a clew as to the probable nature of the gypsum and anhydrite deposits. The results of a study of one of these cores are given in figure 6. The commingling of gypsum, anhydrite and limestone in various proportions which characterize all the cores available is well illustrated. It is to be noted that 4 mineralized zones were encountered between 943 and 1,015 feet in depth and that 28 feet of core contained gypsum and/or anhydrite.

Iowa, Kansas, Michigan and Ohio are all important Middle Western gypsum-producing states and the deposits from which the gypsum is obtained are generally at the surface or not much more than 100 feet below the surface. Whether or not it would be possible to produce gypsum and anhydrite from Illinois deposits on a commercially competitive basis cannot be determined from the data at hand. However, it does appear worth while to indicate the existence of the Illinois deposits and the possibility that the gypsum and anhydrite horizon in the St. Louis formation may be found by careful prospecting at a relatively shallow depth in the southwest part of the area shown in figure 5.

WAX- OR RESIN-BEARING LIMESTONE

In Calhoun County (fig. 4) there outcrops a stratum of wax-or resin-bearing limestone which so far as is known is not duplicated elsewhere in the State. The deposit is probably a part of the Decorah formation and underlies the Kimmswick formation which is a high calcium limestone. It may be the stratigraphic equivalent of the "oil rock" of the Illinois-Wisconsin lead and zinc area.[17] The extent of the wax- or resin-bearing limestone bed has not been determined but it appears likely that it underlies a considerable area. An exposure in the NE. ¼ SE. ¼ NE. ¼ sec. 6, T. 12 S., R. 2 W., shows 7 feet of the limestone and this represents only a part of the total thickness of the bed as the bottom of the stratum was covered by stream deposits.

---

[16] MacTaggart, E. F., Gypsum anhydrite as a base for plaster products: Rock Products, vol. 40, no. 7, pp. 46-48, July, 1937.

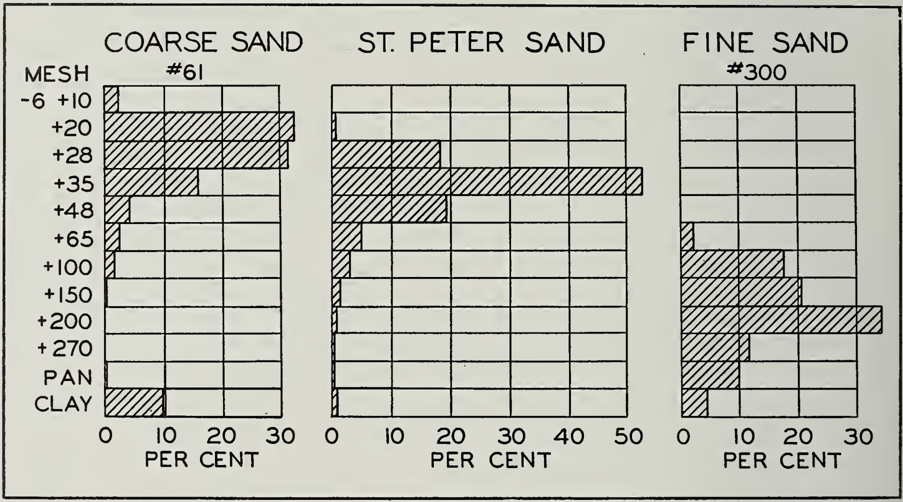


Figure 2.—Mechanical composition of a coarse sand and a fine sand from southern Illinois in contrast with a sample of St. Peter sand from the Ottawa district.

The limestone is a chocolate brown but weathers a light gray or almost white. It occurs in beds 3 to 6 inches thick and thin partings of shale are present between some of the limestone beds. This shale will burn when ignited with a match. A chemical analysis of a sample of the limestone is shown in figure 4. These data indicate that the limestone is somewhat impure, the chief impurity being silica, and that it is low in Fe_2O_3. The combustible carbon figure results from the wax or resin present.

The wax or resin occurs mostly as irregular, brownish-yellow masses disseminated through the limestone. A few brownish colored particles having definite outlines are also present and may be plant remains.

It is estimated that the combustible carbon figure shown in the chemical analysis is equivalent to a value of about 500 B. t. u. per pound of limestone.

---

[17] Bain, H. F., Zinc and lead deposits of the upper Mississippi Valley: U. S. Geol. Survey Bull. 294, pp. 25-27, 1906.
Trowbridge, A. C., and Shaw, E. W., Geology and geography of the Galena and Elizabeth quadrangles: Illinois Geol. Survey Bull. 26, p. 47, 1916.

A ton of the limestone would, therefore, contain about 1.000.000 B. t. u. which is equivalent to the B. t. u. in about 80 pounds of good Illinois coal.

The chemical composition of this limestone compares favorably with some natural cement rocks which have been used for making natural cement, though many of the limestones so used are higher in silica and alumina. Whether the rock can be used for making natural cement or some other similar product has not been investigated but the unique combination of low iron content and the wax or resin fuel is of interest. Probably the presence of wax or resin alone is sufficient to justify description of the limestone; the possibilities for the recovery of this wax or resin may bear study.

The deposit is located about 1½ miles from Mississippi River and about the same distance from a power transmission line. No rail transportation is available. Conditions for underground mining appear to be good.

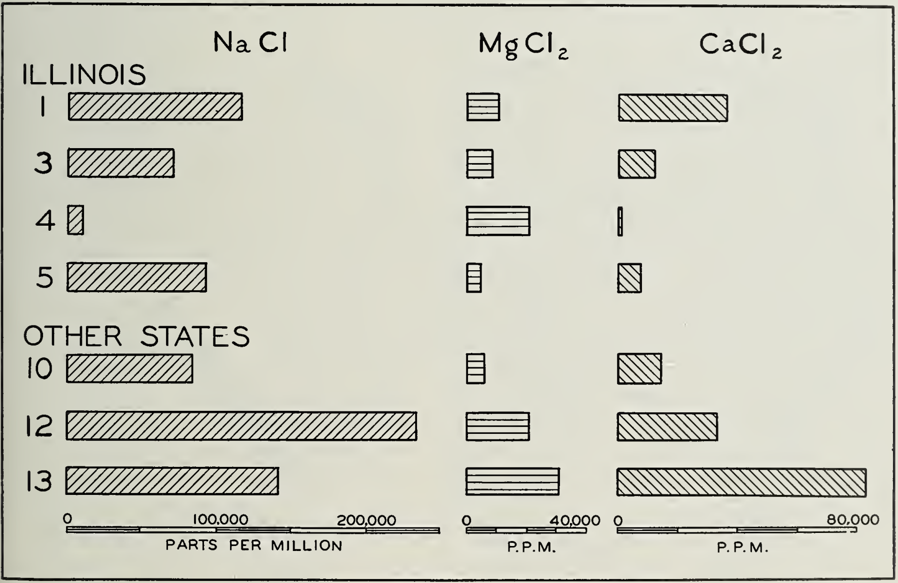


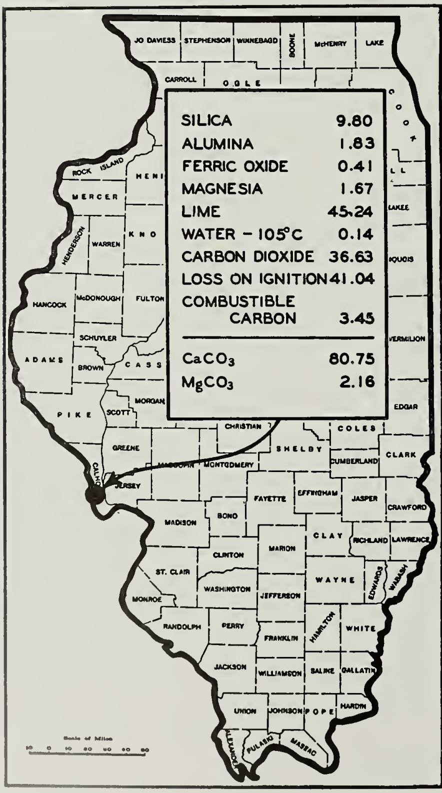
FIGURE 3.—Comparison of Illinois brines with those from other states. Data in parts per million (see table 1).

QUARTZITIC SANDSTONE

In two localities of extreme southern Illinois, there occur deposits of sandstone whose grains are firmly cemented by quartz. In a sense they are quartzites but since the degree of cementation is not as firm as that of the Minnesota and Wisconsin quartzites familiar in the Middle West, the term quartzitic sandstone is used.

About 6 miles below Golconda in the bluffs of Ohio River in the NW. 1/4 NW. 1/4 sec. 13, T. 14 S., R. 6 E., Pope County, there is exposed 30 feet of sandstone, most of it quartzitic, which is a part of the Bethel formation. The total thickness of the quartzitic sandstone may be considerably more than 30 feet. The sandstone layers vary from an inch to 8 inches or more thick and many of them are separated by shale partings. These partings facilitate the quarrying of blocks or slabs. The sandstone is light brown or gray in color and contains small brown iron-stained spots. Some layers of clayey sandstone are present. The deposit is located on Ohio River but is not near any railroad. Quarrying conditions are favorable for the production of large amounts of sandstone.

Another quartzitic sandstone outcrops in Rineking Hill cut along the Southern Illinois and Kentucky Railroad near the village of Round Knob,



SILICA	9.80
ALUMINA	1.83
FERRIC OXIDE	0.41
MAGNESIA	1.67
LIME	45.24
WATER – 105°C	0.14
CARBON DIOXIDE	36.63
LOSS ON IGNITION	41.04
COMBUSTIBLE CARBON	3.45
$CaCO_3$	80.75
$MgCO_3$	2.16

FIGURE 4.

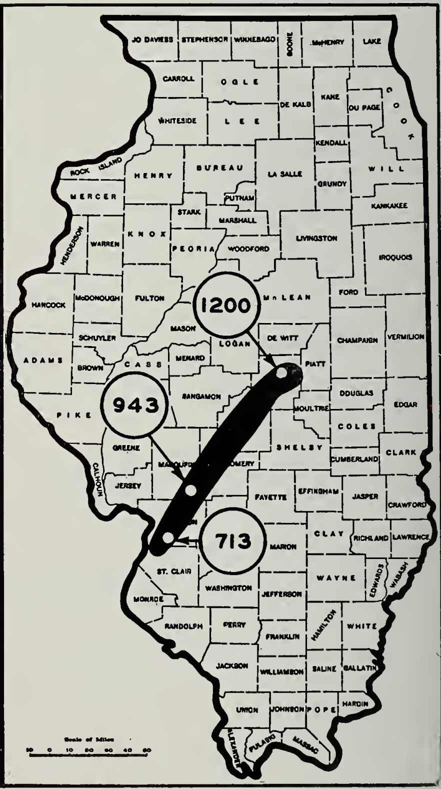


FIGURE 5.

FIGURE 4.—Location and chemical composition of wax or resin-bearing limestone.

FIGURE 5.—Area of Gypsiferous St. Louis formation in central and southern Illinois. The numbers indicate the depth to the gypsum horizon. Data furnished by L. E. Workman.

Massac County in the E. ½ NE. ¼ sec. 23, T. 14 S., R. 4 E. About 15 feet of white to gray quartzitic sandstone is exposed. It occurs in beds 1 to 6 inches or more thick. The deposit shows considerable folding and thorough prospecting is necessary to determine whether sufficient sandstone is available under a reasonable amount of overburden to warrant possible exploitation. Overburden is unconsolidated sand and clay.

No tests have been made on the last mentioned sandstone but the Pope County sandstone gave results in preliminary tests which suggest it may have use in making silica brick although crushing produced a higher per cent of fines than in the case of Minnesota quartzites. The sandstone would probably make a good decorative flagstone and tests indicate that it will withstand temperatures of 3000° F. without fusion. It may, therefore, be useful as firestone for foundry cupolas and for lining pickling vats in the metallurgical industry. Some of the sandstone has been used for riprap along Ohio River. Possibly the Massac County sandstone and likewise a number of other Illinois sandstones may also be suitable for some of the same purposes.

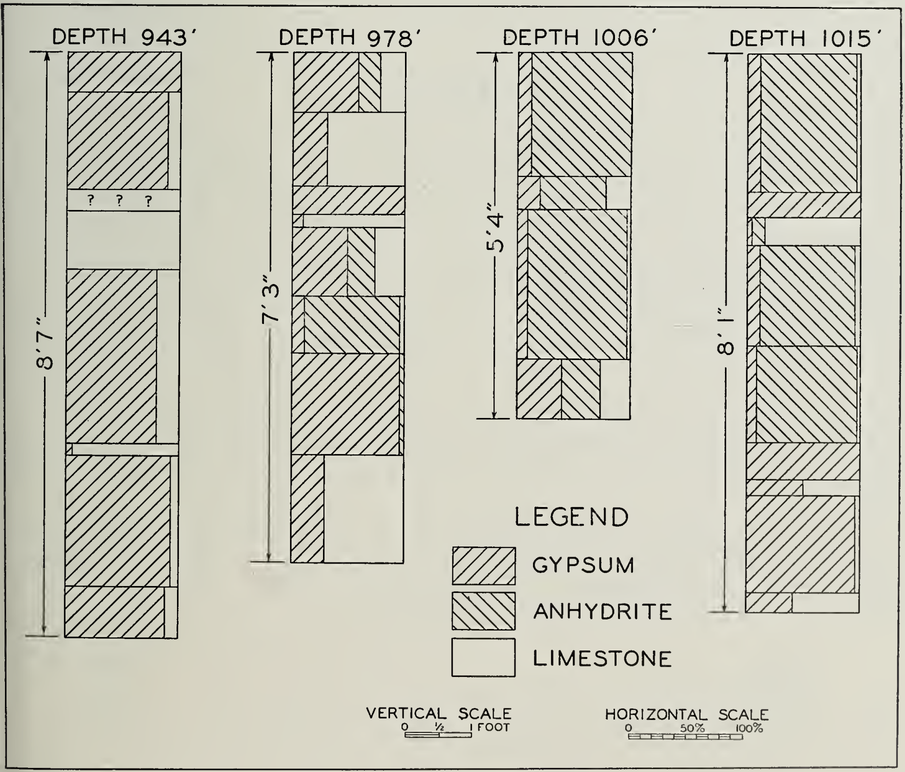


Figure 6.—Distribution, depth, thickness, and estimated relative percentages of gypsum, anhydrite, and limestone in core of well located in southeastern Macoupin County.

COLORED CLAYS AND SANDS

Colored sands and shales are quite widespread throughout the State and deposits occur in such number and diversity that no attempt will be made to discuss their distribution. It does seem worthwhile, however, to present a few observations regarding them. Red shales and clays occur at a number of places, maroon clays are known, a deposit of purple shale has been observed and likewise deposits of green clay and shale and brown clay and shale. Some of these clays and shales particularly the reds, are rather strongly colored and consideration is warranted of their possibilities as low grade pigments, particularly for mortars and concrete. Investigation of their value as colored fillers may also be worth while.

Brown and yellow sands, and more rarely orange and red sands occur in many parts of Illinois. Some of them burn red. Most of them are moderately high in clay and their color is due to iron oxides. The question is raised whether they may not have value as a coloring material to be used as a part of the fine aggregate for mortar and concrete. Likewise, the fact that many of them burn an attractive color suggests that they may be of value for sanding or veneering brick.

LIMONITE

Although it is not generally known, Illinois at one time had a flourishing iron-making industry which depended upon deposits of Illinois limonite for ore. Hardin County was the site of this industry and two furnaces were operated there. The limonite deposits resulted from the decay of limestone and other rocks and consisted of small pellets and larger irregular chunks scattered through clay and soil. The deepest accumulations of this kind are likely to be located on the sides of knobs or spurs and some of the old ore pits are said to have been 90 feet deep. "All the known occurrences of iron ore deposits in Hardin County are in areas underlain by the Fredonia or St. Louis limestones and in that particular they are like most of the extensive limonite deposits in eastern United States, as in Pennsylvania and Alabama."[18]

Usually the Hardin County limonite now visible is yellow, brown or red. No recent analyses have been made but an early report on the ore from the bank of one of the early furnaces is as follows:[18]

	Per Cent
Water	10.8
Siliceous earth	5.0
Fe_2O_3	80.0
Alumina	3.7
Loss and alkalies not estimated	0.5
	100.0

---

[18] Butts, Chas., Geology of Hardin County: Illinois Geol. Survey Bull. 41, p. 305, 1920.

There is probably a considerable quantity of limonite in Hardin County but the nature of the deposits makes estimates impossible without detailed and extensive exploration. The deposits lie about 3 to 3½ miles northwest of Elizabethtown, which is located on Ohio River. No railroad is close at hand.

The limonite deposits of Hardin County are no longer important as sources of iron ore. It may be, however, that they could be used as a source of mineral pigment. The raw ground limonite is yellow brown in color, it can be burned red or maroon.

SIDERITE

The mineral siderite, which is ferrous carbonate, occurs in Illinois mainly as nodules or thin layers in the Coal Measures shales. The nodules are commonly disc shaped, varying in length from about 2 to 12 inches and are usually less than 4 inches thick. The beds are commonly less than 3 inches thick and are generally lenticular. The nodules or beds are mostly gray or dark gray on the inside and where they have been exposed to the weather have an exterior coating of brown or yellow hydrated iron oxide. They contain variable amounts of clay and some also contain calcium carbonate. The latter causes them to effervesce with cold hydrochloric acid. The term "clay ironstone" concretions is often applied to the sideritic nodules.

No extensive investigation has been made of the chemical composition of the sideritic nodules but two samples showed respectively 31.3 per cent and 47.3 per cent Fe_2O_3, which is equivalent roughly to 50 and 75 per cent ferrous carbonate.

The sideritic concretions and beds are comparatively common in a number of the thicker Coal Measures shale formations, especially in the basal 5 to 10 feet. They have been noted in the Canton, Purington, Farmington, and Francis Creek shales, which outcrop extensively in northern and western Illinois. No exact data are available regarding the quantity of these concretions present in the various shales but it is estimated that in places the sideritic materials constitute 5 per cent and possibly as much as 10 per cent of the shales.

It is not known that the Illinois sideritic concretions have any commercial value, however, their possible uses are not known to have been investigated.

SUMMARY

Illinois contains a variety of little used mineral resources which merit consideration. These include potash shale, greensand, coarse and fine sands, peat, marl, "slates" and slaty shales, brines, gypsum and anhydrite, wax or resin bearing limestone, quartzitic sandstone, colored clays and sands, iron ore, and siderite, but little is known in detail about most of these resources and their possible uses. Each of them might merit research as a part of the Survey's program were not other more important problems of wider interest and greater potential returns demanding attention. It seems worth while, however, to call the attention of the Illinois mineral industry to these minor resources so that benefit may accrue to any of the industries which by reason of technical knowledge, geographic location or business relations are able to advantageously exploit one or more of these resources.

MAGNETIC SEPARATORS AND THEIR POSSIBLE APPLICATIONS TO THE BENEFICIATION OF ILLINOIS INDUSTRIAL MINERALS

By

J. J. Ferris

Chief Engineer, Dings Magnetic Separator Company, Milwaukee

Before going to the application of magnetic separators to Illinois minerals, I want to outline briefly the art of magnetic separation. In general, magnetic separation can be divided into four classifications.

The first and most common is the removal of tramp iron such as nuts, bolts, coupling pins, etc., from material going to crushers, pulverizers, grinding mills and similar equipment. Tramp iron passing into a grinding circuit causes considerable damage and often fires; and a magnetic separator properly applied prevents this. Some of the materials being so treated in Illinois includes coal, gypsum, fluorspar and many others. The most popular type of magnetic separator used for this application is the magnetic pulley, but where a magnetic pulley cannot be installed, a spout magnet which becomes part of the spout or chute, or a suspended magnet, may be installed with satisfactory results.

The second general classification is the removal of deleterious iron, such as scale, iron of abrasion, and other iron oxides, from materials which are so contaminated. For this application many standard and special type separators are available, and recent improvements in high intensity magnetic separators has widened this field considerably. Typical applications include the purification of glass sand, bauxite, fluorspar, clays and other minerals.

The third classification is the reclamation of materials. Occasionally the iron only is wanted, but more often two or more materials are mechanically combined and the mixture, as such, is practically valueless. After separation, however, the value of each separate material is increased considerably. The separation of ferrous and non-ferrous borings and turnings, the recovery of iron from foundry refuse, and the separation of iron from slag, are but a few examples of this application. The type of separator required is the medium intensity machine, and the size and style depends, of course, upon conditions.

The fourth classification is the concentration of minerals and ores, to raise the grade and eliminate the gangue. A typical application is the concentration of zinc and lead in the Galena, Illinois, district.

The zinc and lead ores there are the sulphides and they are associated with pyrite. Lead separates very readily from the zinc and the pyrite through the specific gravity method, jigs and tables, but the concentrates from the jigs or tables must be roasted so as to make the pyrite magnetic. When roasted the pyrite is readily separated from the zinc.

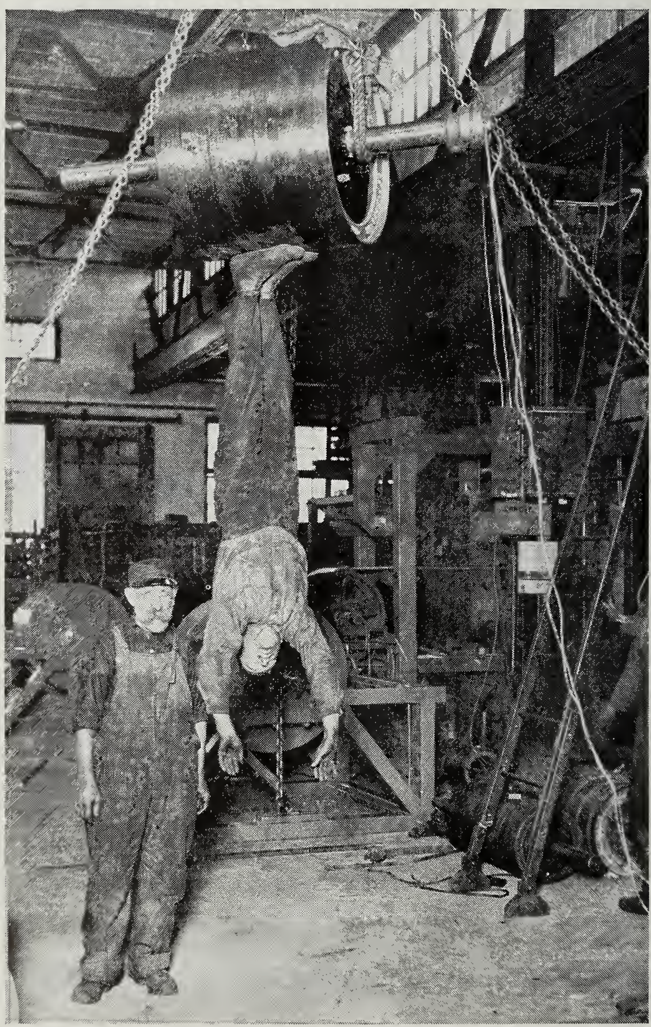


FIGURE 7.—The man being held suspended face downward by the attraction of the magnetism of the magnetic pulley for the iron in his shoes illustrates the tremendous strength of the high intensity magnetic pulley. This is a graphic illustration of the power that can be attained when the design incorporates the proper proportion of copper wire and dynamo steel.

In the early years of magnetic separation in the Galena district, the pyrite was given what is called a sweet roast. The combination of zinc and pyrite was roasted anywhere from two to four hours at a bright red temperature. Such a roast made the pyrite very magnetic and ordinary medium intensity separators and even low intensity separators qualified for the separation. This heavy roast, however, resulted in the loss of the sulphur and it was soon discovered that by subjecting the mixture to a lighter skin roast, merely coating the outside surface with a magnetic iron oxide, that a high intensity separator would produce the desired results. This combination consequently resulted in the saving of the sulphur because very little of it was lost and the skin roasted pyrite was delivered to the sulphuric acid plant and practically all of the sulphur was recovered.

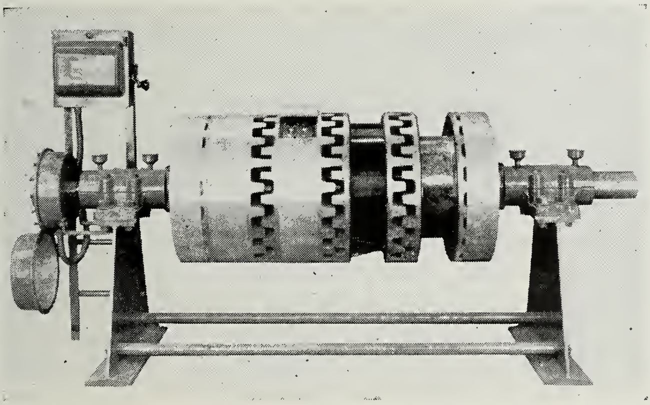


Figure 8.—The new air-cooled magnetic pulley has longitudinal and radial air circulating ducts. The surfaces are corrugated and promote a maximum amount of circulating surface. Tests have proved that, with this new design, an increase of strength up to 20 per cent is obtained. The use of bronze spacer rings is further assurance of the highest possible magnetic intensity.

At first high intensity separators had limited capacities as compared to the lower intensity type, but developments in the high intensity separator design has brought about the so-called super high intensity induction type separator, which involves the application of highly magnetized laminated rolls through induction from powerfully energized primary magnetic poles.

Illinois' greatest non-metallic mineral, of course, is coal. When mining much tramp iron finds its way into that coal. Even under ground, coal cutting knives, drill points, chains, railroad spikes, and other railroad iron, tools, etc., are hoisted to the surface with the coal. After the coal leaves the tipples more iron finds its way into it. Bolts, nuts and rivets become detached from the steel railroad cars and where whole carloads of coal are dumped by car dumping equipment, even brake shoes, handwheels and coupling pins fall with the coal.

The wide use of pulverized and stoker coal makes necessary the extraction of that miscellaneous tramp iron from it. Crushers must be protected from it, the pulverizers produce a highly explosive mixture which, when ignited through a spark, causes disastrous results, and even loss of lives.

It is a matter of record that some large consumers of coal recover enough iron to make the sale of it profitable. With handwheels, coupling pins and coal cutting knives worth considerably more than scrap, it has been found to be quite profitable to sort these parts from each other and sell them back to the original owner.

In several cases where coal yards were thoroughly cleaned up for repairs or for other reasons, so much iron had accumulated at the bottom of the coal piles that the crushers and pulverizers would have been fed a very high proportion of tramp iron if the magnetic separator had not been interposed between the coal pile and that machinery.

Illinois coal particularly has a high sulphur content. That sulphur exists in the form of iron pyrite. When taking into account the amount of unburned carbon falling through stoker grates, this type of firing at best is most uneconomical. Ordinary stoker cinders may contain as high as 40% unburned carbon. The balance of those cinders is roasted pyrite and ash. A simple screening process will eliminate the ash and you then have a combination of roasted pyrite, which is magnetic, and unburned carbon. The process of separation is almost identical to that encountered in the zinc district. The separator readily removes the roasted pyrite, not useable, however, for sulphuric acid, because it has been sweet roasted, and the unburnt carbon is easily recovered. That carbon, of course, does not have the B.t.u. value that the original coal had, because the hydrocarbon gases have been burned out.

This process of reclaiming unburned carbon from cinders is extensively used in Germany. Much work has been done on the process in this country, but at this moment it is not considered practical or economical, because coal is still so cheap that it really amounts to spending one dollar to save another.

Another problem involving the reclamation of the iron from powdered fuel fly-ash has been given some thought and study. The idea is far fetched and will probably never be commercial. The iron pyrite, where powdered coal is used, had been ground up finely and when burning this powdered coal the sulphur is thoroughly burned off. Flyash is a mixture of fine particles of iron and ash. The two are easily separated, but, as stated, the recovered iron costs more than it is worth.

The next largest non-metallic mineral in Illinois is silica. The Ottawa sands are world famous. Most of this silica, existing as St. Peter sandstone, is found in Kendall, LaSalle and Ogle counties. When these deposits were formed very little native iron ore found its way there. To be sure there is considerable animal and vegetable matter associated with this silica, but by washing, these two are very readily eliminated. Further, much of the small amount of iron encountered exists in the form of oxides or rust. That, too, is quite easily washed off in part, but native magnetite and fine iron of abrasion is extracted by magnetic separators.

Without thorough washing and magnetic separation the average so-called Ottawa sand never ran over 0.04 per cent Fe_2O_3. Washing and separation easily brings that iron content down to 0.025 per cent Fe_2O_3 and much of the sand, when thoroughly processed, will run as low as 0.014 per cent Fe_2O_3.

In many parts much more money is spent to produce silica containing 0.06 per cent Fe_2O_3. As stated, the Ottawa sand is world famous because of its low iron content, its fine structure and its proper alumina content, and other good qualities; and Ottawa could very nicely get along and compete with other sands by merely washing and drying, but in order to excel all other sands offered they do separate magnetically with both medium and high

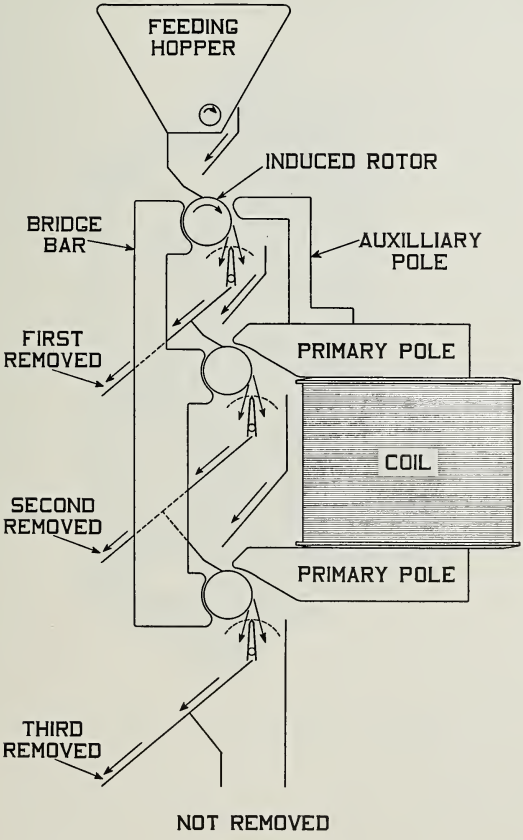


FIGURE 9.—Diagram illustrating the principle of the high intensity magnetic separator.

The high intensity type of magnetic separator developed by our company is the most efficient commercial machine manufactured today and separations heretofore considered impossible have been accomplished on this machine.

Typical applications are the purification of bauxite, reducing the iron content of chemical ore to a point required by the manufacturers of alum; reduction of iron content of silica sand used in the manufacture of glass; reduction of iron content in nepheline syenite, feldspar, borax and similar materials. In addition, this machine is used for concentrating tungsten, ilmenite, monozite, zircon, and similar feebly magnetic materials.

A laboratory is maintained by our company where complete magnetic analyses can be made on materials which may lend themselves to magnetic treatment. Many of the leading industries have had their problems solved in this laboratory.

"WASCHER'S"
LIBRARY BINDERS
507 S. Goodwin
Urbana, Ill.